PERFORMANCE ANALYSIS AND COMPARISON OF ENERGY EFFICIENT MASSIVE MIMO ANTENNA SELECTION ALGORITHMS

MASTER OF SCIENCE THESIS

BY

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HAWASSA UNIVERSITY, HAWASSA ETHIOPIA

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Place: Hawassa, Ethiopia

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Declaration

I hereby declare that the thesis "**Performance Analysis and Comparison of Energy Efficient Massive MIMO Antenna Selection Algorithms**" is my own work conducted under the guidance of Dr. Feyisa Debo, Department of Electrical and computer Engineering, Hawassa University Institute of Technology, HAWASSA (Sidama Region), Ethiopia.

I further declare that to the best of my knowledge the thesis does not contain any part of work that has been submitted for the award of any degree either in this university or some other university without appropriate note.

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This is to certify that the statement made above by the candidate is true to the best of my knowledge and it has been submitted for examination with my approval as a university advisor.

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Abstract

Massive multi-input multi-output system plays a key role in the next-generation (5G) wireless communication systems, which are equipped with a large number of antennas at the base station of a network to improve cell capacity for network communication systems and this technology employs a lot amount of antennas at the base station (BS) and can reach high data rates under favorable propagation conditions and using simple linear processing. However massive MIMO downlink systems have some drawbacks, such as the high bulk antenna which leads power consumption device at the base stations, so that the power consumptions of the radio frequency chains can be huge, which poses great challenges. All radio frequency (RF) chains required in BS equipped with each number of transmit antennas this implies the hardware energy consumption may not significantly increase. A way to deal with this issue is to utilize antenna selection algorithms and through assuming equal power allocation among the users at the Base Stations. Antenna selection algorithm scheme is one method to achieve sum-rate and assess energy efficiency in massive MIMO systems and reducing the number of RF chains transmitter out of M transmitter antenna. The main aim of this thesis work to analyze and compare energy efficient Massive MIMO antenna selection algorithms. The selected energy efficient massive MIMO antenna selection algorithms are random antenna selection (RASA), norm based antenna selection (NBASA) and greedy antenna selection algorithm (GASA) to select the sub-optimal set of the number of antennas that produce attain sum-rate from the available M antennas at BS of the massive downlink MIMO system at perfect CSI. We compare the performance of massive MIMO antenna selection based on achieved sum-rate, transmitted number of selected antenna, M transmit antennas, users, SNR and energy efficiency and simulate those antenna selection schemes using matlab software. As we obtain from simulation result the greedy antenna selection algorithm leads to best achieved sum-rate and energy efficiency than NBASA and RASA under total power constraint in massive MIMO systems.

Key Words: Massive MIMO, Antenna selection in Ma-MIMO, Equal power allocation, Sum-rate, Energy efficiency, RASA, NBASA, GASA, PCSI.

Table contents

List of Figure

List of Table

List of Abbreviations

5G	Fifth-Generations
ADC	Analog to Digital Converter
AWGN	Additive White Gaussian Noise
BS	Base Station
BW	Bandwidth
CCA	Compress Cylindrical Array
CSI	Channel State Information
DAC	Digital to Analog Converter
DL	Downlink
EE	Energy Efficient
EPA	Equal Power Allocation
ESASA	Exhaustive Search Antenna Selection Algorithm
FDD	Frequency Division Duplex
GASA	Greedy Antenna Selection Algorithm
H	Matrix H
HLA	Huge Linear Array
I	Unit Matrix
i.i.d	Independent and Identically Distributed
IAS	Iterative Antenna Selection
K	Number of Users

LTE	Long Term Evolution (4G)
M	Number BS of Antennas
Ma-MIMO	Massive Multiple-Input Multiple-Output
MIMO	Multiple-Input Multiple-Output
MU-MIMO	Multi User Multi Input Multi Output
n	The Noise Vector
NBASA	Norm Base Antenna Selection Algorithm
Pmax	Maximum Power Available at the BS
R	Achievable Sum Rate
$\mathbb{R}$	Set of Real Numbers
RASA	Random Antenna Selection Algorithm
RFC	Radio Frequency Chain
S	Cardinality Set of Selected Antennas
SDMA	Singular Division Multiplexing Access
TA	Transmit Antenna
TDD	Time Division Duplex
UEs	User Equipment’s
UL	Uplink
W	Beamforming Matrix
ZF	Zero Force Beamforming

List of Symbols

$argmax(.)$	Index of the maximum entry in a vector
a	Path loss exponent
$E(.)$	Expectation
$\triangleq$	Equality by definition
C	Set of complex numbers
σ^2	Noise variance
β_k	Large-scale fading component of user k
α_m	Antenna index that is set to 1 if antenna m is activated and to 0 otherwise
p_k	Portion of equal power allocated to user k
g_k	Small-scale fading channel vector of user k
d_k	Distance between the BS and user k
$T_r(.)$	Trace of a square matrix
R_k	Spatial correlation matrix
P_{cir}	Fixed power consumed by each activated RF chain
I_S	Identity matrix with trace S
H_s	Selected channel matrix between the MBS and users
C_M^S	Binomial coefficient$\frac{M!}{S!(M-S)!}$
h_k	Estimated channel vector of user k
$\lfloor . \rfloor$	Floor function
$\lVert . \rVert$	Euclidean norm of a vector

$\lceil . \rceil$	Ceiling function
$\|.\|_F$	Frobenius norm of a matrix
$(.)^T$	Transpose of a matrix
$(.)^H$	Hermitian of a matrix
Σ	Spatial correlation only between transmit antennas

CHAPTER ONE

1.1. Introduction

MIMO technology trusts on several antennas to instantaneously transmit various data streams in cellular wireless communication systems. It has already been used in present commercial long term evolution wireless communication systems and certainly be used in succeeding generation wireless communication systems due to its excessive potential of high spectral efficiency, low latency, more reliability and extra strengths. The development of MIMO technology is carried on through point-to-point MIMO, Multi-user MIMO and Massive MIMO. Massive MIMO which referred as large scale MIMO or scaling up MIMO) [1] offers big advantages over conventional point-to-point MIMO and Multi-user MIMO with current practice through the use of a large excess of service-antennas over terminals and time-division duplex (TDD) operation [2]. One of its main objectives is to increase by several orders of magnitude the rate offered by the current cellular systems. This prototype is largely accepted as a candidate for the design of future (5G) cellular networks since it provides several gains, such as high throughput and promising core technology in future wideband wireless communication system which arouses considerable interest in both telecommunication industry and academia. Multi-user operation with large scale base station antennas is advocated in [3],[4] where a single-cell TDD model was considered.

A Ma-MIMO system serves for next generation (5G) wireless network based on using few hundreds of antennas simultaneously to serve rare of users in the same time-frequency resource. The diversity of big number of antennas denotes quasi-orthogonality among the users' channels in consequence of the law of large numbers [5]. Hence, linear transmitters and receivers based on spatial multiplexing achieve high performance[6],[7]. It's inheriting the benefits of conventional MIMO systems. The introduction of numerous antennas implies a quasi-orthogonal of the channels. The transmission can be done on the same time-frequency resources, therefore increase in the number of transmit antennas requires more resources [8],[9], but by using antenna selection scheme technique of resources allocation in Ma-MIMO system consumed power per antennas decreases.

Thus, they may deploy low power consumed Ma-MIMO system by reducing radio frequency chain through selecting antenna and using other techniques at BS [11],[10]. Furthermore, as the number of antennas becomes large, the power consumed by the circuit of RF chains is no longer neglected [12],[13]. Therefore, the circuit power consumed must be taken into consideration when enhancing system performance.

1.1.1. Motivation

Even though energy efficiency is regarded as one of the key metrics for realistic executions of future large scale MIMO systems, most of the energy efficient Ma-MIMO technologies still present a major number of open problems. In fact, Ma-MIMO systems supposed that each antenna has dedicated radio frequency chain transceiver, hence scaling up MIMO means scaling up the number of RFC transmitter and antennas. So this is the main challenge for this technology in terms of hardware cost, energy efficiency, size, channel matrix rank and power consumption. Subsequently it often leads unsustainable power consumptions either at the transmitter or at the receiver side and this implies that unbounded energy can be achieved by increasing the number of M antennas at BS. Therefore, we cannot always benefit from increasing the number of RF transceivers because of huge number of antennas at BS to assist only some number of users. By considering these consequences, we take the circuit power consumption into account by antenna selection algorithms schemes for quite desirable for the upcoming low-cost communication.

Considerations of the proposed antenna selection algorithms scheme is specifically designed for very large antenna downlink MIMO systems. It’s particularly appropriate, since it allows to exploit the higher diversity offered by a large number of antennas and the power savings deriving from applying a lower number of RF chains. However, their design metrics are based on the reducing number of RFC in large downlink MIMO system for more efficient approaches that can further increase energy efficiency. We motivated to reduce the number of RFC transmitters in Ma-MIMO system by antenna selection algorithms. Though antenna selection algorithm schemes in DL-Ma-MIMO is deliver interesting benefits for energy efficient in large-scale systems. This justifies the search for a novel transmission scheme, in order to attain the achieve energy efficiency.

Finally, to show the Ma-MIMO antenna selection scheme that near-sub-optimal performances in case of achievable sum-rate and energy efficiency through toughly reduced number of RF chains at the transmitter and utilize significant way of communication in a multiuser scenario. Within this framework we more precisely focused on how to achieve sum-rate from large antennas by selecting antenna with high channel gain by using different antenna selection scheme that is aimed to evaluate energy efficiency presented at the downlink Ma-MIMO systems. This is essential and must be studied for the future of wireless communications.

1.2. Literature Review

There is unlike types of research looked into the performance of the antenna selection algorithm techniques in these downlink massive MIMO TDD operating systems. The ultimate aim is to design novel innovative network architectures and technologies desired to encounter the explosive increase in cellular data demand without increasing the power consumption. Related to this work are briefly reviewed below.

In [14] introduced capacity-based antenna selection algorithm at the receiver in single cell multiuser downlink MIMO system, which achieve the sum capacity. In this paper the sum capacity achieved. The analysis is carried out on the comparison of fast antenna selection algorithm and optimal antenna selection algorithm. Author suggested that OASA have better achieve the sum capacity and have more complexity, where FAS provide approach performance with low complexity. Based on this the author does not considered achieving data rate and energy efficiency at the transmitter simultaneously in multi cell multi-user downlink MIMO system. In [15] investigated channel capacity and bit error rate using antenna selection schemes in downlink Massive MIMO system. Using optimal number of transmit antenna 100 and number of receivers antenna less than 10. BPSK affords well BER performance than QPSK and QAM modulation systems and if the channel capacity of the cell is better than a sealed threshold, number of transmit antennas, subset of transmit antennas and servable mobile terminals are mutually optimized to achievement energy efficiency and concludes that for small values of circuit power consumption, maximum energy efficiency can be obtained.

In [16] considered to shows a performance analysis of norm, capacity and CBA with low complexity for energy efficiency maximation based on channel gain. NBS's method selects the transmit antennas matching to the column of the channel matrix with the largest Euclidean norms with low complexity. The correlation-based selection (CBS) procedure has been deliberated the correlation among any two columns of the channel matrix and it searches the two columns with the highest correlation and removes the one with the smaller norm. Capacity-based selection algorithm achieved energy efficiency than NBS and CBS because chooses the column which makes the largest gain and this algorithm accomplishes a near-optimal solution with high computational complexity. The author do not analyzed EE in terms of sum-rate versus number of selected antenna, transmit M antenna and users. Besides he suggested that using low complex incremental selection algorithm (ISA) is better to make more EE in infinite Ma-MIMO system.

In [17] had introduced an entire-array and sub array switching networks for the antenna selection in large scale-MIMO channels and analyzed BAB algorithms for antenna selection; this analysis produced an effective outcome for large scale MIMO. However, the challenges are radio frequency entire switching networks are less power efficient with large scale MIMO system. In [18] proposes transmit antenna selection in the downlink of Massive MIMO system with dirty-paper coding. Selection criterion is to maximize the DPC capacity based on compress cylindrical array and huge linear array by using convex optimization for selecting the antenna subset that maximizes the capacity based on SNR in the downlink. The performance of cylindrical array is better than the linear array; but difficult to deploy due to its large size, and author does not consider, sum-rate and appraising energy efficiency by assuming circuit power consumption in DL Massive MIMO considering number of transmitted selected antenna.

In [19] the author proposes an antenna selection algorithm, Particle Swarm Optimization algorithm (PSO) and Genetic Algorithm (GA) in downlink Ma-MIMO system under PCSI using zero forcing precoding through equal and unequal power allocation. The author achieves better antenna selection with higher capacity, however Genetic Algorithm (GA) achieves better capacity than PSO and it’s commonly considered as slow optimization schemes, but the limitation are achieve sum-rate through optimal ASA and the assessment of energy efficiency. In [20] investigated a massive MIMO system. The challenge in using large antenna array is the increased power consumption and high complexity of associated circuitry. An antenna selection approach is used to combat these problems. Further, energy efficiency analysis is carried out using a power consumption model. It is seen that assess energy efficiency using the proposed antenna selection method as compared to the system without antenna selection.

In [21] a novel antenna selection combining scheme is given for Ma-MIMO system. Here the consequence of spatial correlativity and imperfect channel estimation is deliberated. The basic purpose is to decrease the effective number of antennas without degrading system performance. Antenna selection vector is calculated by using orthogonal matching pursuit algorithm to reduce cost and hardware complexity of the system. Here one restriction is that the given scheme studies only for single user system not for multi-user system. In [22] have suggested an algorithm which bids maximizing of number of RFC to be activated in order to achieve the sum-rate at downlink Ma- MIMO TDD operation with PCSI. It is to observe that achieve sum-rate is not achieved by activating all the radio frequency chains. This problem requires the use of ASA. Performance of different antenna selection strategies like brute force search (BFS) is compared with the proposed antenna selection and also analyzed its complexity during antenna selection, however BFS search AS is best performance at small number of M transmit antenna, but very complex and not perfectly visible in Ma-MIMO. In these scenarios the author do not simultaneously achieves sum-rate and assesses EE as function of selected antenna and M, transmit antenna. In [23] had introduced antenna selection techniques for MIMO-OFDM systems in the perspective of EE and also made an interchange among energy efficiency–spectral efficiency. He proved that the greedy algorithm based antenna selection provides better energy efficiency compared to formal MIMO systems exhibit loss in energy efficiency , however the challenge are in multi-user MIMO-OFDMA finite dimensional antenna arrays.

1.3. Statement of the Problem

The power consumption problem in the existing massive MIMO technology treat leads to highly power expenditure. In large scale MIMO multiple antennas require multiple RF chains which consists amplifier, mixer, DAC/ADC, and all analog device. Those factors do not neglect the power used by the radio frequency chains and signal processing of the transceivers, especially when the number of antennas increases. Hence, energy efficient will not necessarily increase by employing more antennas in the case of massive MIMO systems, which results in energy efficiency problem with respect to the increment number of antennas and many other analog devices that connect to antenna and residuals loss factors.

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1.4. Objectives

1.4.1. General Objective

To analyze and compare the performance of energy efficient massive MIMO antenna selection algorithms

1.4.2. Specific Objective

- To develop system design model for down link massive MIMO antenna selection algorithm.
- To analyze sum-rate in RASA, NBASA and GASA in downlink massive MIMO systems
- To compare performance of RASA, NBASA and GASA based on an achieved sum-rate, transmitted number of selected antenna, M transmit antennas, users SNR and energy efficiency in downlink massive MIMO systems.
- To evaluate energy efficiency for RASA, NBASA and GASA in downlink massive MIMO systems based on achievable sum-rate.
- To simulate RASA, NBASA and GASA based on an achieved sum-rate, transmitted number of selected antenna, M transmit antennas, users SNR and energy efficiency in downlink massive MIMO systems using Matlab software.

1.5. Gaps of Reviewed Related Literature

- A Massive-MIMO antenna selection algorithm is presented with low complexity AS scheme. The achievable sum-capacity of a system over quasi-static Gaussian independent and identically distributed (i.i.d) Rayleigh flat fading channels are considered, however author not deliberate to achieve sum-rate and maximize energy efficiency using CCA and HLA antenna selection algorithms in terms of dirty-paper coding based on SNR antennas and with other low linear processing.
- The optimization algorithm and genetic algorithm antenna selection schemes are compared in downlink Ma-MIMO to achieve significant performance in terms of capacity, but it does not analyze the effect of number of transmits antennas at BS and users on the system with ZF to minimize MUI and achieve sum-rate.
- One part of research gap is well explained and an optimal antenna selection algorithm is compared with fast antenna selection algorithms in uplink MIMO system. But while computing the capacity of each antenna the complexity, circuit power consumption and evaluate energy efficiency, the effect of large number of antenna is not taken into account in downlink Ma-MIMO systems.
- The drawback of the author is rejoined that contrary what adopted in the literature in terms of investigating and manipulative circuit power consumption in downlink large MIMO. It is multi-level ideal which also considers the power consumed by analog components (P_{mixer}, P_{filter} and P_{DAC}) used for the transmitters BS antenna and power consumed by M, number of antenna. The model can be extended and integrated with efficient antenna selection algorithm to reduce power consumed in the systems. Due to limitation in Ma-MIMO technology in terms of power expenditure in the system, low complex efficient antenna selection scheme proposed that opposite in the literature which uses initialization, iterative, update procedure to execute and it is extremely easy to evaluate the influence of the different parameters. By selecting the best sub-set of transmit antennas based on channel gain, most of it can provide significant performance.
- Analysis of downlink large-scale MIMO multi antenna systems through the low complex efficient antenna selection scheme is based on existing approaches from the literature.

The performances of the proposed schemes are analysis through extensive numerical simulations and show the achievable sum-rate through different parameters. Investigate the efficient AS algorithm for decreasing the consumed power in a massive MIMO downlink transmission. Analytical and numerical results prove that the proposed metric allows to greatly reduce both power consumption and computational complexity of downlink massive MIMO, especially when compared to large-scale systems where no existing AS schemes from the literature are employed. Jointly antenna selection scheme and equal power allocated are analyzed and performed simultaneously according to exploiting metrics to achieved sum-rate. The results show that the proposed schemes (RASA, NBASA and GASA) are existed both in terms of sum-rate and evaluating energy efficiency that differs from the previous work.

- Two main key performance indicators are considered in this study, namely the achieved sum-rate and evaluated EE simultaneously in terms of variable selected antenna, users and SNR. In the first step, the algorithm analyzes the sum-rate (throughput) performance of Ma-MIMO system when antenna selection is applied at the transmitter's side. In the second step, we investigate the achievable sum-rate and assess EE for single cell multi users in downlink Ma-MIMO systems depending on the rate gained by each selected antenna.
- The optimal antenna selection algorithms have more complexity in Ma-MIMO wireless communication because it takes huge time to select and it is one of the limitations of antenna selection schemes in this technology to make EE. So we consider low complexity antenna selection algorithms schemes at downlink Ma-MIMO since number of base station antenna is typically much larger than number of users. As far as these low complexity antenna selection algorithm schemes are concerned, RASA, NBASA and GASA were analyzed and compared under large number of M, transmitted antenna; transmitted selected antenna and users at PCSI downlink Ma-MIMO systems.
- The achievable sum-rate for downlink Ma-MIMO antenna selection algorithm with variable selected antenna, M transmitted antenna, users K, SNR and evaluated EE in term of those above parameter are compared.

1.6. Research Methodology

In the first period of the investigation, a literature review of earlier and present works on the area of MIMO, MU-MIMO, and large scale MIMO are widely conducted to broaden the perspective on such areas of study. Furthermore, state of the art associated to those lectured issues is deeply researched and intensively explored during this period. Following the literature review phase, analyzing starts to formulating achieve sum-rate and assess energy efficiency problem. Bid of different complicated circuit power consumption model analyzed. All these are used to compute closed-form expression under efficient antenna selection algorithm to achieve high performance.

Located on the inputs addressed from review of related literatures and the statement of the problem in mind, the methodology of this study is designed as follows

- Outline work flows for assess energy efficiency of the system
- Assemble goal network demands in terms of evaluating energy efficiency
- Prepare efficient antenna selection algorithm and analysis its mathematical model for calculating the achieved sum-rate (and assess energy efficiency of the systems.
    - ✓ Consider under perfect channel state information at transmitters,
    - ✓ Defining antenna selection algorithm matrices with their power constraints,
    - ✓ Calculating the achieved sum-rate (throughput) of each user,
- Calculating total sum-rate of all users under equal power allocation, hence total sum-rate of the system and finally taking an average of all over realization to find the final system of evaluated energy efficiency.
- Describe all input parameters for simulation.

Simulations:

- Describe system model of DL Ma-MIMO antenna selection algorithm.
- Execute aim network for prediction achieved sum-rate (throughput) and measure EE simulations by MAT LAB software.
- Finally, all the simulations were performed based on using analytical and numerical result.

Thesis Outline

This thesis mainly deals with performance analysis and comparison of massive MIMO antenna selection based on three antenna selection algorithms scheme including GASA, NBASA and RASA in mathematical and simulation approaches. A single cell multi users massive MIMO system is built in this system which equips number of M antenna at BS and serves different number of users with single received antenna. In particular, a computational efficient antenna selection and equal power allocation will be designed for achieving sum-rate and evaluate energy efficiency of the massive MIMO antenna selection system. Besides, the impact of the amount of transmitted antenna on achievable rate will be judged under different antenna selection algorithms. Based on this, circuit power consumption will be also deliberated. Finally, sub-optimal and better antenna selection scheme will be presented in order to achieve the significant usage of resources. This thesis is organized as follows;

- Chapter one includes the introduction to the upbringing of 5G technology of Ma-MIMO wireless communication systems. The importance is laid on the want for large user wireless communication systems MIMO, MU-MIMO and Ma-MIMO are the basic that cooperative wireless communication system. The issues of growing mobile data, numerous great user systems, motivation, and review literature, statement of the problem, objective, research gap methodology and the different techniques used in these systems are also described.
- Chapter two provides the background studies of massive MIMO system, Channel Estimation, long description of perfect CSIT, UL, DL and discuses about channel hardening and favorable propagation related to different properties and some linear precoding in M-MIMO system.
- Chapter three would analyze mathematical model and formulas related to antenna selection algorithms methods and assess energy efficiency. As well as analyze and compare the performance of the GASA, NBASA with RASA and those methods which are functional to evaluate energy efficiency in downlink Ma-MIMO systems.

Based on theoretical knowledge, efficient antenna selection strategies programs will be given.

- Chapter four provides the simulation results and discussion of M-MIMO antenna selection for system including the GASA, NBASA and RASA.
- Chapter five, the conclusion and suggestions for future work were presented.

CHAPTER TWO

2.1. Massive MIMO Systems Background

Ma-MIMO systems are carried up versions of MU-MIMO systems that aim to defeat the main issues of multiuser MIMO. There are some important distinctions between Ma-MIMO and formal MU-MIMO. In Ma-MIMO only the BS learns H, so a single-antenna terminal may be cheap than in MU-MIMO systems[24],[25],[26] M is typically much larger (normally ranging from 50 to 1000) than K, increasing the data rate capacity, while reducing the radiated power by each individual antenna and, simultaneously, increasing the number of terminals that can be attended. Simple linear digital signal processing is near optimal and it is used in both the uplink and the downlink [27],[30],[31] and the large scale MIMO system permits numerous parallel communications in the same time and frequency resource that called SDMA [32],[33]. It refers to the system where the BS communicates with several users concurrently. The Ma-MIMO, BS and the user can be equipped with multiple antennas. Merits of Massive-MIMO systems:

- Increased data rate, due to base station is equipped with many antennas; it sends the independent data streams to many users simultaneously.
- Ultra- reliability; due to those antennas generate a lot of communication paths that the radio signal can propagate over diversity gain.
- Improving the energy efficiency, due to that base station is able to focus its transmission power into the spatial direction where each user is located or array gain.

The fundamental futures deliver Massive MIMO scalable with respect to the number of BS antennas, M are;

- Only the base station learns channel state information (CSI) of H
- Channel hardening and M is typically >>K
- Simply linear signal processing is used both on the uplink and on the downlink Ma-MIMO system and asymptotic favorable propagation, etc.…

Figure below shows a simplified single-cell massive MIMO network with an M antenna base station and K single-antenna terminals. Either in the contrary link or in forward link transmissions, all terminals occupy the full time-frequency resources simultaneously [34]. In the reverse link, the base station has to recover the individual signals transmitted by the terminals. In the forward link, the base station has to ensure that each terminal receiver only the signal intended for it [28],[29]. The base station's multiplexing and de-multiplexing signal processing is made possible by utilizing a large number of antennas and by its CSI knowledge.

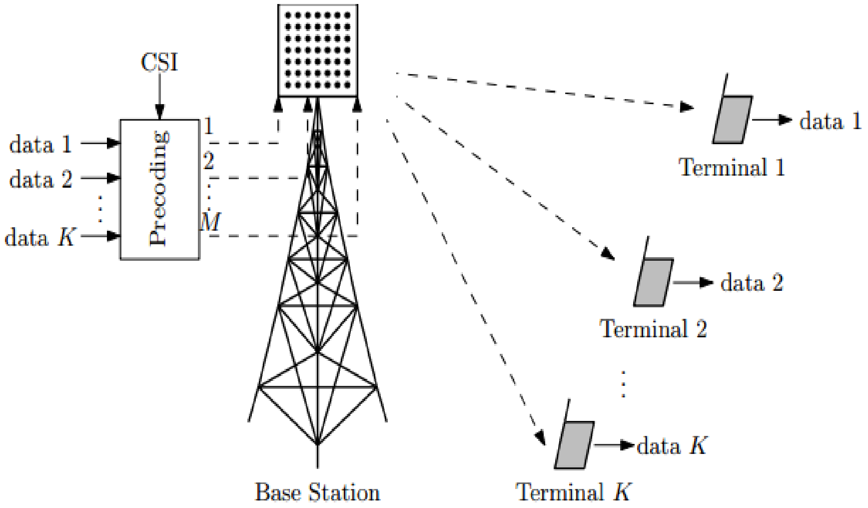

Figure2. 1: Downlink Ma-MIMO system with M, antenna BS and K single antenna users [34].

Allow h_{km} be the channel gain among the kth terminal, and the mth base station antenna. We will accept that the base station antennas are arranged in a compact array, so as to the paths among a given terminal, and all base station antennas are impressed by the same large-scale fading, but by altered small-scale fading

$$h_{km} = \sqrt{\beta_k} g_{km} \qquad k = 1, \dots . K, m = 1 \dots . M, \tag{2.1}$$

where $\sqrt{\beta_k}$ is a large-scale fading coefficient that depends on k but not on m, and g_{km} signifies the effect of small-scale fading and H as (2.4) to be a matrix that comprises the channel gains among all terminals, and all base station antenna. Through all performance analyses, are undertake that the small-scale fading is Rayleigh and independent between the antennas, and the terminals, so that h_{km} are (i.i.d) $\mathcal{CN}(0,1)$ random variables.

2.2. Pilot Signals and Channel Estimation

Point-to-point MIMO, MU-MIMO, and Ma-MIMO involve different degrees of CSI knowledge at the BS and at the terminal [35],[36]. This CSI may be obtained either by estimation from received pilot signals, or by feedback from the transmitter to receiver, or by combining both strategies. Acquiring the channel by sending pilots consumes resources that might be differently used to transmit data. To facilitate channel estimation at the receiver, during each segment of the time-frequency plane over the coherence interval, a single pilot waveform needs to be allocated to each transmitting antenna, and all pilots need to be mutually orthogonal.

2.3. Channel Estimation

The Base Station wants CSI to discover the signals transmitted from the users in the uplink, and to precode the signals in the downlink [37]. This CSI is gained through the uplink training. Each user is assigned an orthogonal pilot sequence, and sends this pilot sequence to the Base Station. The Base Station knows the pilot’s sequences transmitted from all users, and then estimates the channels based they received pilot signals.

Additionally each user may want partial cognition of CSI to coherently detect the signals transmitted from the Base Station. This information can be learned through downlink training or some blind channel estimation algorithm. Since the Base Station uses linear precoding methods to beamform the signals to the users, the user wants only the real channel gain (which is a scalar constant) to detect its desired signals. Therefore, the Base Station can spend a short time to beamform pilots in the downlink for CSI acquisition at the users. Then as we have expected so far that the BS and the users have perfect CSI [37], however in practice, this CSI has to be approximated. Depending on the system duplexing mode (TDD or FDD), the channel estimation systems are very unlike.

2.3.1. Channel Estimation in TDD Systems

In a time division duplex system, the uplink and downlink broadcasts use the same frequency range, but dissimilar time slots. The uplink and downlink channels are reciprocal. Thus, the CSI can be gained by using following scheme.

For the uplink transmission: the Base Station needs CSI to detect the signals transmitted from the K users. This CSI is estimated at the BS. More exactly, the K terminals send K orthogonal pilot sequences to the Base Station on the uplink. Then the BS approximates the channels based on the received pilot signals. This process requires a minimum of K channel uses [38].

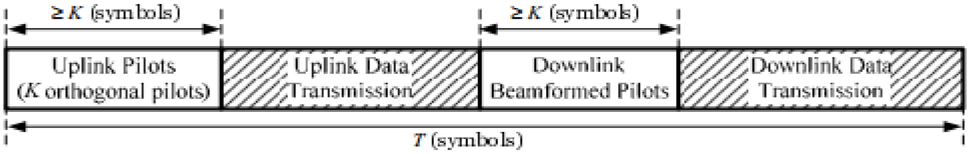

Figure2. 2: Slot structure and channel estimation in TDD systems [38]

For the downlink: The Base Station requires CSI to precode of the transmitted signals while each user requires the effective channel gain to discover the desired signals. Due to the channel reciprocity, the channel approximated at the Base Station in the uplink can be used to precode of the transmit symbols. To obtain knowledge of the effective channel gain, the BS can beamform pilots, and each user can estimate the effective channel gains based on the received pilot signals. This requires at least K channel users. Totally, the training procedure needs a minimum of 2K channel users. We accept that the channel stays constant over T symbols. Thus, it is required that 2K <T. An illustration of channel estimation in TDD systems is shown in Figure 2.2.

2.3.2. Channel Estimation in FDD Systems

In an FDD system, the uplink and downlink transmissions use different frequency spectrum, and hence, the uplink and downlink channels are not reciprocal. The channel knowledge at the BS and users can be obtained by using following training scheme.

For the downlink transmission: the BS needs CSI to precode the symbols before transmitting to the K users. The BS antennas transmit M orthogonal pilot sequences to K users [39]. All users will approximate the channel based on the received pilots. Then it feeds back its channel estimates (M channel estimates) to the BS through the uplink. This process requires at least M channel uses for the downlink and M channel uses for the uplink

For the uplink transmission: the BS needs CSI to decode the signals transmitted from the K users. One simple way is that the K users transmit K orthogonal pilot sequences to the BS. Then, the BS will estimate the channels based on the received pilot signals. This process requires at least K channel uses for the uplink.

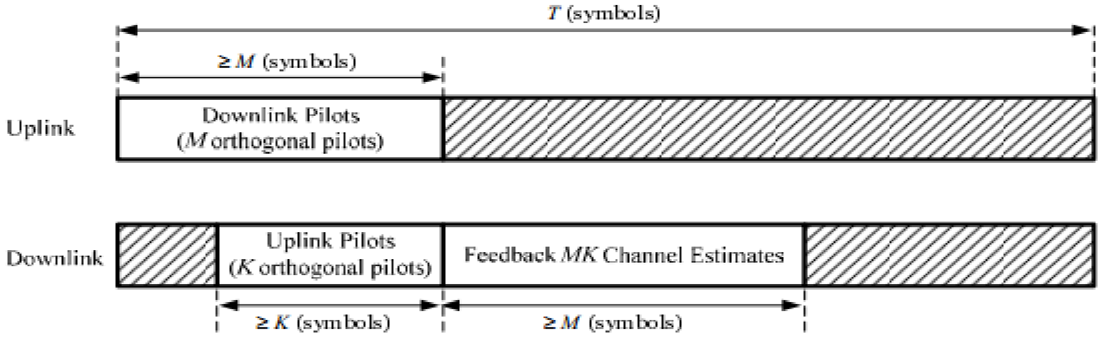

Figure2. 3: Slot construction and channel estimation in FDD systems [38].

Consequently, the entire channel estimation process needs at least M + K channel uses in the uplink and M channel uses in the downlink [40],[41],[42]. Adopt that the distances of the coherence intervals for the uplink and the downlink are the same and are identical to T. Then we have the constraints: M < T and M + K < T. Consequently, M +K < T is the constraint for frequency time division (FDD) systems. An illustration of channel estimation in FDD systems is shown in Figure 2.3.

2.4. In What Way Massive MIMO Deeds

In Massive-MIMO, time duplex division operation is preferable. In a coherence interval, there are three jobs: channel estimation including the uplink training and the downlink training, uplink data transmission, and downlink data transmission. A time duplex division Massive-MIMO protocol is shown in Figure 2.2.

2.5. Downlink Data Transmission System

Forward link (downlink) is the scenario where the BS transmits signals to entirely K-the users are denoting $y_k \in C^{K\times 1}$ as the received signal vector. For most anterior work in Ma-MIMO, time-division Duplexing, where the downlink channel is the reverse of the uplink channel matrix. Instantly, the received signal path can be conveyed as

$$y_{dl,k} = \sqrt{\rho_d} H_K^T x_k + n_k \tag{2.2}$$

where $x_k \in \mathbb{C}^{M\times 1}$ is the signal vector transmitted by the BS, $n_k \in \mathbb{C}^{M\times 1}$ is a realizatation of the AWGN random vector n which is expected to be circularly symmetric complex Gaussian distributed and $H \in \mathbb{C}^{M\times K}$ is the multiple-access channel matrix among the base station antenna array and the set of terminals' antennas and ρ_d is the transmit power of the downlink. To normalize the transmit power, we assume $E\{\|x\|^2\} = 1$. The Base Station commonly has chanel state information matching to all users based on uplink pilot transmission. Consequently, it is possible for the Base Station to execute power allocation to achieve the sum transmission rate. With power allocation, the sum capacity for the system is [43],[44].

$$C = \max_{P} \log_2 \det(I_M + \rho_d H P H^H) \approx \max_{P} \log_2 \det(I_K + \rho_d M P D) \text{bits/Hz} \qquad (2.3)$$

Where P is a positive diagonal matrix with the power allocations as its diagonal elements and $\sum_{K=1}^{K} P_k = 1$.

For instance the BS wants to transmit the messages (data) to each terminal, but it has to ensure that each terminal receives only the message intended to it. To do so, the BS can aggregate the channel approxmate gained in the uplink training phase [45],[46],[47],[66], with the vector containing the messages designated to the terminals to acquire the actual signal to be transmitted. This combination is also known as precoding. Basically,when the message vector is attained via a linear mapping, i.e., by multiplying q by a matrix we are acting a linear precoding [48],[49]. In contrast, when there is a nonlinear mapping, the employed precoder is nonlinear. Figure 2.4 illustrates the process of transmitting data in the downlink direction.

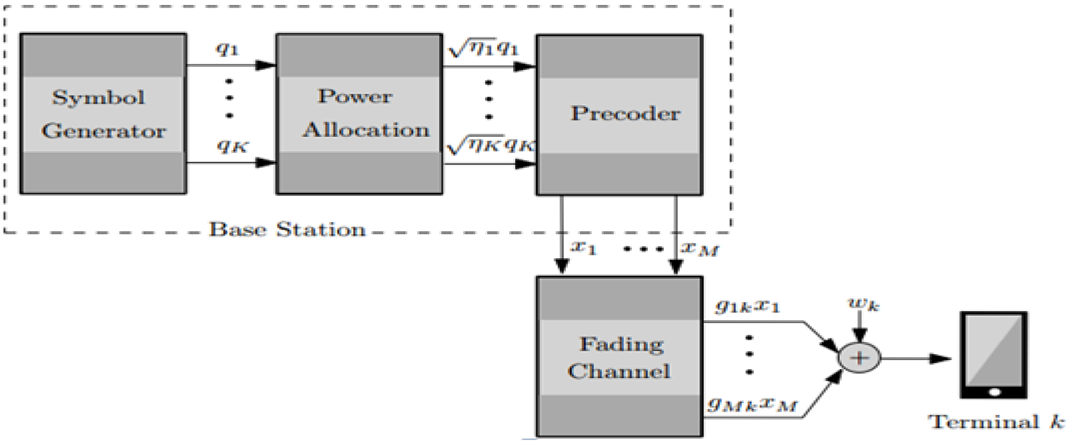

Figure2. 4: Downlink data transmission to terminal k [66].

where $q = [q_1 \dots . q_K]^T$ is the vector composed of the messages from all terminals.

2.6. Channel Matrix

In a single-cell system, the channel response for terminal k to the BS is denoted by $h_k \in c^{Mx1}$, where each element of h_k is the channel response from the terminal to one of the M antennas -BS [43],[50],[51],[66]. Let H be a matrix including the channel responses for all the users in the cell to the base station,

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1K} \\ \vdots & & \ddots & \vdots \\ h_{K1} & h_{K2} & \cdots & h_{KM} \end{bmatrix} \tag{2.4}$$

and h_k is the kth column of H. An illustration of the channel matrix is provided in Figure 2.5.

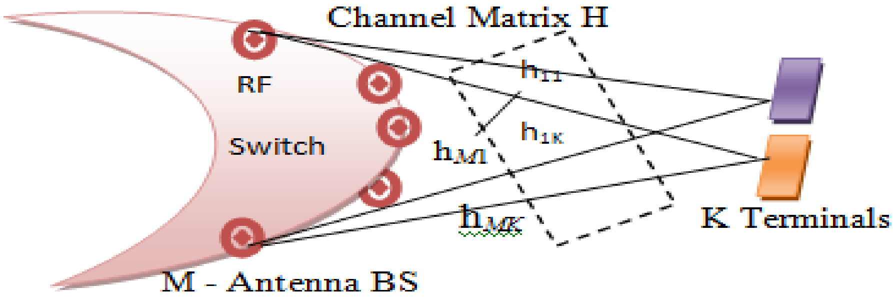

Figure2. 5: Channel matrix between BS and terminals.

2.7. Channel Hardening and Favorable Propagation

Channel hardening and favorable propagation are two linked, but different properties. Channel hardening denotes that a fading channel acts as an almost deterministic channel [52]. Favorable propagation means that the channel vectors from different users are almost orthogonal [53]. These are both significances of the law of huge numbers.

2.7.1. Channel Hardening

Channel hardening makes a fading channel behave as deterministic so that the random fluctuations in the channel due to microscopic changes in the propagation environment become negligible [54],[55]. This property alleviates the need for battling small-scale fading and improves the downlink channel gain estimation. A propagation channel h_k provides asymptotic channel hardening if the gain $\|h_k\|_2^2$ of the fading channel is close to its mean value as the number of antennas increases,

$$\frac{\|h_k\|_2^2}{E[\|h_k\|_2^2]} \rightarrow 1, \mathrm{M} \rightarrow \infty \tag{2.5}$$

Equation (2.5) also implies that

$$\mathrm{Var}\left[\frac{\|h_k\|_2^2}{E[\|h_k\|_2^2]}\right] = \frac{\mathrm{Var}\left[\|h_k\|_2^2\right]}{\left(E\left[\|h_k\|_2^2\right]\right)^2} \rightarrow 0, \mathrm{M} \rightarrow \infty \tag{2.6}$$

Moreover, by applying lemma

$$\left[E(h_k^H h_k)^2\right] = \left(tr(IR_k)\right)^2 + tr\left(I(R_k)^2 I^H\right), \tag{2.7}$$

From [55] in (2.5), we obtain

$$\frac{\mathrm{Var}\left[\|\mathrm{h_k}\|_2^2\right]}{\left(\left[\|\mathrm{h_k}\|_2^2\right]\right)^2} = \frac{\left(\mathrm{tr}(\mathrm{R_k})\right)^2 + \mathrm{tr}\left((\mathrm{R_k})^2\right) - \left(\mathrm{tr}(\mathrm{R_k})\right)^2}{\left(\mathrm{tr}(\mathrm{R_k})\right)^2} \tag{2.8}$$

$$= \frac{\mathrm{tr}\left((\mathrm{R_k})^2\right)}{\left(\mathrm{tr}(\mathrm{R_k})\right)^2} = \mathrm{tr}\left((\mathrm{R_k})^2\right) / (\mathrm{M}\beta_\mathrm{k})^2$$

Therefore, if the variance in (2.8) is not close to zero as M increases, one can assure that the channel does not harden [56]. Thus, we can compute the variance in equation (2.8) for both uncorrelated and correlated fading channels to check if channel hardening is observed. First, observe that $t_r((R_k)^2)$ in the numerator of (2.8) is the sum of the squared eigenvalues of R_k. In the case of uncorrelated fading, all the eigenvalues are equal to β_k and hence $R_k = \beta_k I_{(M)}$ where β_k is the coefficient regarding the large-scale fading effect. Thus, equation (2.8) become

$$\frac{tr\left((R_k)^2\right)}{(M\beta_k)^2} = \frac{tr\left((\beta_k I_{(M)})^2\right)}{(M\beta_K)^2} = \frac{M\beta_k^2}{(M\beta_k)^2} = \frac{1}{M} \rightarrow 0, M \rightarrow \infty \tag{2.9}$$

which confirms the presence of channel hardening. On the other hand, in the case of correlated fading, R_k is not diagonal in general. Hence, strong spatial correlation is qualified by large eigenvalues variations which thereby decrease the level of channel hardening that is detected for a given number of antennas. Then, more antennas are required to achieve a certain value in (2.8) under spatially correlated fading than with uncorrelated fading.

2.7.2. Favorable Propagation

Favorable propagation is observed if the channel vector h_k, for k = 1…K are pair wisely orthogonal [52],[56], that is, if

$$h_k^H h_{k'} \begin{cases} 0, k, k' = 1 \dots . K, k \neq k' \\ \|h_k\|_2^2 \neq 0, k = 1 \dots K. \end{cases} \tag{2.10}$$

Unfortunately, the condition in (2.10) is not true in practice. However, we can investigate if the channel offers approximately favorable propagation. The pair of channels h_k and $h_{k'}$ provide asymptotically favorable propagation if

$$\frac{h_k^H h_{k'}}{\sqrt{E\left[\|h_k\|_2^2\right] E\left[\|h_{k'}\|_2^2\right]}} \to 0, M \to \infty \tag{2.11}$$

This means that the inner product of the normalized channels $h_{k'}/\sqrt{E\left[\|h_k\|_2^2\right]}$ and $h_k/\sqrt{E\left[\|h_{k'}\|_2^2\right]}$ goes asymptotically to zero. Mostly the favorable propagation deliberation (2.11) does not offer only the optimal performance with linear processing [53],but also shows the most needed condition from the outlook of maximizing the information rate.

2.7.3. Favorable Propagation for Arbitrary Channels

The idea of favorable propagation was obtainable for a deterministic multiple access channel H, but in practice, H will be a realization of a random matrix H due to the arbitrarily nature inherent to fading. Therefore, it is of supreme important to examine if favorable propagation takes place on average. The favorable propagation is investigating the behavior of $h_k^H h_{k'}$ on average that described in (2.11). The favorable propagation will be considered for two particular scenarios, independent Rayleigh fading channel and spatial multipath channel. In independent Rayleigh channel the situation of system operates in a thick, rich scattering environment with signal being received from all directions [34],[53] where as in spatial multipath channel, the channel model stated before deliberates that the received signals arrive from all directions independently, which means that the environment has rich scattering and no spatial correlation.

CHAPTER THREE

3.1. Systems and Mathematical Models

As shown in fig 3.1 below we consider a single cell multi-user massive MIMO system with a single Base Station equipped with M antennas and single-antenna user equipment's (UEs). For simplicity, we only consider the downlink data communication link from BS to UEs. It should be noted that the derived theories, algorithms, in this thesis can be potentially used for the downlink massive MIMO systems. In this system, M transmit independent data streams (one data stream per UE) within the same frequency and time resource. The base station is having *M* antennas serving the *K* users with $M \gg K$, and sharing the resource block belonging to same time-frequency unit. At the BS, the assumption of perfect channel state information (CSI) is made. Antenna selection executes at BS among the available *M* antennas choosing *S* best antennas in the cell and by allocates equal power to the users.

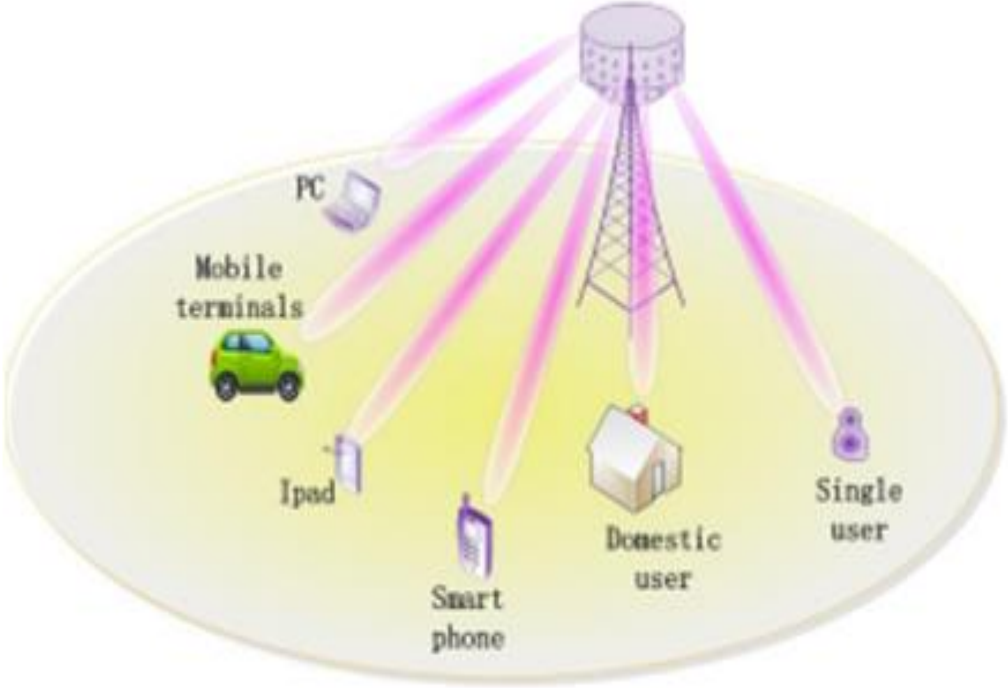

Figure3. 1: Downlink massive MIMO systems [56].

In the downlink massive MIMO systems where the BS is equipped with a huge number of M antennas choosing S best antennas attending K single-antenna users with M ≫ K.

G denote the $K{\times}M$ flat-fading channel matrix gain between the BS and the K users with $h_{mk} \triangleq [G]_{mk}$ being the channel coefficient between the mth antenna of the BS and the kth user then it can be written as

$$G = D^{1/2}H \tag{3.1}$$

D is a K × K diagonal matrix. Where $[D]_{kk}$=diag $\{\beta_1, \beta_2 \ldots \beta_K\}$ denotes the large-scale fading matrix with its elements $\beta_k = \varphi\varsigma/d_k^{\alpha}$. The large-scale fading is expected to be known at BS, whereas small-scale fading is to be approximated in each coherence interval [56]. Considering small scale fading under favorable propagation condition, the complex channel gain matrix $[H = h_1, h_2, \ldots h_k]$ where $h_k \in \mathbb{C}^{Mx1}$ is the kth channel vector for user k is assumed to be quasi-static Gaussian independent and identically distributed (i. i. d) flat fading channel. We can use the uncorrelated Rayleigh fading and to model h_{km} as a realization of the random variable $h_k \sim \mathcal{CN}\left(0_{(M)}, \beta_k I_{(M)}\right)$ thus, $h_k$can be modeled as $h_k = g_{mk}\sqrt{\beta_k}$. Considering only path loss, the large scale fading is defined by the vector $\beta_k = \varphi\varsigma\frac{d_k^{-a}}{d_o^{-a}}$, where ς represents the shadow fading with long normal distribution , $log_{10}\varsigma \sim \mathcal{N}(0, \sigma^2)$, α is the path loss , d_o is the reference distance exponent, d_k the distance among the base station and terminals k, D is a diagonal matrix defined as D = diag (d). Where β_k is a large-scale coefficient dependent only on k and $g_{mk}$is the realization of a random variable distributed which represents the effect of small-scale fading. The vector $p = p_1, p_2 \ldots p_k$ is assumed to be the distribution of power among users under perfectly the channel states information and zero forcing as beamforming strategy (ZFB) because it cancels the multi-user interference and it achieves high performance [57],[58],[59]. Accordingly, the downlink channel matrix among the selected antennas and the K users can be outlined as $H(\alpha) = [h_1(\alpha), h_2(\alpha), \ldots h_K(\alpha)]$ as stated above. Where $h_K \epsilon \mathbb{C}^{Mx1}$ is given by $h_k(\alpha)^T$ equal's $\Sigma^{1/2}\, h_k$ estimated channel vector for users k. The beamforming matrix is defined as $W(\alpha) = [w_1(\alpha), w_2(\alpha), \ldots w_K(\alpha)]$ and it's expressed as

$$W_k = \frac{H(\alpha)^H (H(\alpha)H(\alpha)^H)^{-1}}{\eta} \tag{3.2}$$

where eta (η), is the normalization element settled as

$$\eta = \sqrt{\mathrm{T_r}\left\{\left(\mathrm{H}(\alpha)\mathrm{H}(\alpha)^{\mathrm{H}}\right)^{-1}\right\}} \tag{3.3}$$

The received downlink vector of signals is stated as

$$\mathrm{y} = \frac{\mathrm{D}^{\frac{1}{2}}}{\sigma\eta}\mathrm{diag}\left(\sqrt{\mathrm{P}}\right)\mathrm{s} + \mathrm{n} \tag{3.4}$$

$$\sigma = \sqrt{\frac{T_r\{D\}}{K}} \tag{3.5}$$

where σ is normalization factor.

For large scale-MIMO with single cell configuration the k^th user received signal is written as

$$y_{dl,k} = \sqrt{p_k}\sqrt{\beta_k}h_k(a)w_k(a)s_k + \sum_{i=1\neq k}^{K}\sqrt{p_K}\sqrt{\beta_K}h_i(a)w_i(a) + n_k \tag{3.6}$$

3.2. Achievable sum-rate

The Ma-MIMO system sends power to every UEs, taking into account that in the downlink, the transmitted pilot re-use sequence (PRS) delivered from BS to K should be allocated to reduce interference [59]. One method, to measure the system performance, is the achievable rate. The achievable rate is complied by Shannon theorem. This thought expresses the maximum rate, which the transmitter can transmit above the channel. To join a message over a point-to-point scalar channel, the transmitter plots the message onto a sequence of symbols (x_m) and the receiver recuperates the message from the sequence of samples (y_m). The real number of bits carried per transmitted symbol, denoted by R, is called the rate and is assessed in bits per channel use. Recall that a waveform contained in a time-frequency space of bandwidth $B\ H_z$ and time-duration T seconds. Therefore, we measured the rate R in bits per second per Hertz (bits/s/Hz). Generally in sum-rate achievable problems, one critical constraint is the data rate associated with every user should encounter the aim rate as the communication quality guarantee. So the sum-rate achievable problem can be formulated as below. The downlink achievable data rate for the k^th user is expressed based on the Shannon's formula is given below

$$R_k = log_2(1 + SINR_k) \tag{3.7}$$

The sum-rate of k terminals is assumed as

$$R_{sum} = \sum_{k=1}^{K} E\{R_K\} \tag{3.8}$$

3.3. Energy Efficiency

The aim of this section is to quantify the overall power consumption of the large-scale MIMO system and to analyses its energy efficiency performance. Thus, it is considered that the power expenditure in both the downlink and the cooperative links is the sum of the power consumed at the BS, the destination and relays nodes and a fixed constant accounting for the load-independent power consumption. Therefore, increasing the number of antennas might not enhance the system's energy efficiency, since the additional power consumed by the RF chains may actually produce the opposite effect. Therefore, different strategies are there for enhancing the energy efficiency in massive MIMO system. In this thesis we consider antenna selection strategy algorithms to achievable sum- rates and EE in downlink massive MIMO system.

3.3.1. Power Consumption Model

For the number of antennas is huge in the thought system, we assume non-negligible circuit power consumption. Let p_{cir} denotes the fixed power consumed at each activated RF chain (Digital to Analog Converter (DAC), mixer, frequency synthesizer, and filter) and p_{max} the maximal available power at the BS [59],[60],[61]. Furthermore, the circuit power spending for transmit antenna, power required for signal processing and cooling loss are the vital power expenditure factor apart from the transmitter power consumption at the BS [62],[63]. The power feeding model can be written as

$$P_{total} = p_{tx}/\eta + p_{cir} \tag{3.9}$$

where η is the BS's efficiency of power-amplifier, and P_{tx} transmitter power

The power consumption of the circuits related to RF chains is represented by P_{cir}.

The P_{cir} is modeled as

$$P_{cir=}P_{bb} + P_{syn} + \sum_{m=1}^{M} a_m \left(P_{dac} + P_{mix} + P_{filter}\right) \tag{3.10}$$

where , P_{bb} represents invariant spent power for the base-band, P_{dac} is the power consumed by the DAC circuit, P_{mix} characterizes power consumed in the mixer, P_{fil} represents power consumed in the filter (indicates the fixed power spent by each activated RFC) and P_{syn} represents power consumed in the frequency synthesizer.

The circuit power consumption is given below if P_{max} is the maximum available power at the BS as below.

$$\mathrm{p_{out}} + \sum_{\mathrm{m=1}}^{\mathrm{M}} \alpha_{\mathrm{m}}\, \mathrm{p_{cir}} \le \mathrm{p_{max}} - p_{bb} - p_{syn} \tag{3.11}$$

$$\alpha_{\mathrm{m}} = \begin{cases} 1, \text{antenna m is selected} \\ \quad 0, \text{other wiese} \end{cases} \tag{3.12}$$

where α_m is an antenna coefficient or index that is set to 1 if antenna m is selected and to 0 otherwise and we define the vector $\alpha = [\alpha_1, \alpha_2 \ldots \alpha_M]$ and P_{out} is the output transmitted power given by

$$p_{out} = \sum_{k=1}^{K} p_k \tag{3.13}$$

3.3.2. Energy efficiency analysis

A common definition for EE is the ratio of throughput (b/s) over total power consumption (watt). Accordingly, EE in downlink MU-MIMO systems is defined as [64], [65].

$$EE = \frac{\mathrm{R_{total}}}{\mathrm{P_{total}}} \tag{3.14}$$

where R_{tot} is the systems average throughput (total sum-rate) defined in terms of sum-rate. Based on the achievable sum-rate (3.8) and the above total power consumption model, the energy efficiency in (3.14) can be formulated as

$$EE = \frac{R_{total}}{P_{total}} \approx \frac{E \sum_{\mathrm{k=1}}^{\mathrm{K}} (\log_2(\mathrm{R_k}))}{p_{tx}/\eta + P_{cir}} \tag{3.15}$$

$$H_{S^*} = \underset{H_{sel} \in H_{Mt}}{argmax} \; \frac{R_{total}}{P_{total}} \tag{3.16}$$

where $H_{sel} \in H$ is the set of all possible combination of antennas, η is the BS's efficiency of power-amplifier depending on the relation $\eta^2 = K/S - K$ control the power consumption by decrease efficiency power-amplifier (η) through increase antenna selection (S).

There is a tradeoff among the power consumption and the achievable data rate. The energy efficiency rises as increasing the number of antennas, while the power ingestion rises at the same time, resulting in hollow shape of EE curve.

3.4. Antenna Selection in Downlink Ma-MIMO Systems

In theory, Ma-MIMO systems furnish an imposing improvement in performance in comparison to single-input single-output complements regarding connection reliability, data rate and emitted-energy efficiency due to the large number of BS-antennas. Regrettably, increasing the number of antennas at BS may conduce to undesired costs in practice. Ma-MIMO systems with M antenna in single-BS-antennas require M- RFC at the transmitter, which comprise low-noise amplifiers, down converters, and digital-to-analog converters. Therefore, strategies in which the most suitable S out of M antennas are nominated to be active have been proposed to decrease the number of required RFC from M to S [66],[67],[68]. Antenna selection approaches prime to significant savings, but a performance loss is detected when compared to the full system. The key goal is to choice the subset of antennas that conserves the system performance at a sure level. In this chapter, we present the problem of choosing S out of M. BS antennas in the downlink of a single-cell multi-user massive MIMO system as illustrated in Figure 3.2 belows

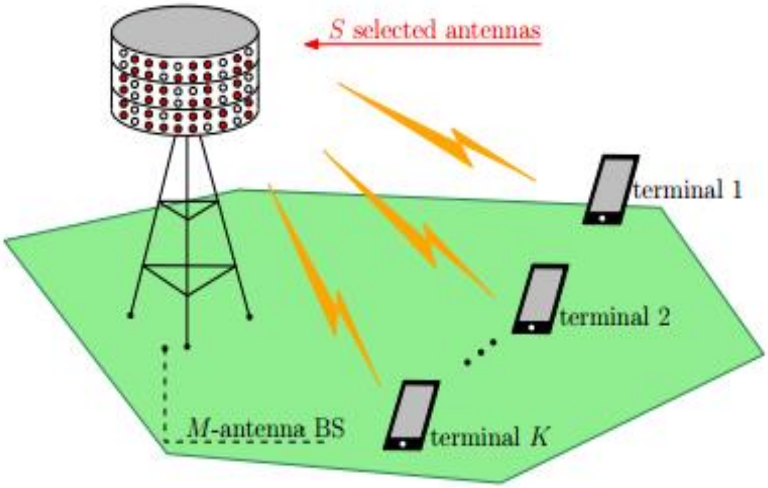

Figure3. 2: Downlink massive MIMO with only S selected BS-antennas [66].

3.4.1. Antenna Selection

A big problem in massive MIMO systems is related to the base station's complexity and power expenditure. The increase in the number of antennas at the base station makes feasible an overplus of theoretical gains, but also imposes many practical challenges [69]. These challenges are mostly related to the RF chains and hardware power consumption [70]. A radio frequency chain contains all analog components before the transmitting antennas, such as power amplifier, mixers, filter, and ADC's/DAC's.

There are some alternatives to reduce the base station's power consumption, like low-complex algorithms to achieve near-optimal throughput,and hybrid analog/digital precoder that perform a digital, and an analogical processing to reduce the number of RF chains [71]. Another best technique is selecting specific antennas to transmit the data and achieve more sum-rate. Therefore, the antenna selection technique reduces the number of active radio frequency chain (RFC) by selecting antennas for time slot, which also reduces the number of active analog elements. This lessening in the number of active radio frequency chains both increases the energy efficiency and decreases the base station's complexity. Antenna selection algorithms was firstly arisen to point-to point MIMO, and the estimation has been used in Ma-MIMO systems as well [72].

For condensed-length and dimension selection we add un unexampled step at the base station processing that described [73] in figure 3.3, under, comprises the antenna selection algorithm which generates matrix $H_S \in \mathbb{C}^{SxK}$. The subscript S, in matrix H_s indicates that S columns are selected out of M in the full channel matrix, H^T. In general, the antenna selection algorithms only have the estimated channel matrix as input.

Directly the number of active antennas is reduced and an antenna selection algorithm is run to select the best set of active transmitting antennas. In this case, S ∈ M antennas are selected to be active, and the received signal by the single-antenna terminals can be written as

$$\mathrm{y} = \sqrt{\rho}\mathrm{H}_\mathrm{S}^\mathrm{T}\alpha + \mathrm{n} \tag{3.17}$$

where $\alpha \in \mathbb{C}^{Sx1}$ is a realization of the random vector α that models the reduced dimension precoded signal, $\rho_{dl} \in R_+$ is the SNR for forward link measured at terminal, $n \in \mathbb{C}^{Kx1}$ is a realization of an AWGN random vector $n \sim \mathcal{CN}\ (0_{kx1}, +I_K)$ and H_S^T is the reduced-dimension broadcast channel. The inferior S in H_S^Tdenotes that the S columns comprising H_S^T were selected from the complete broadcast channel matrix H^T corresponding to the S active antennas.

The signal model in (3.17) can also be represented in terms of the complete forward link channel matrix; in this case, the received signal by the terminals can be rewritten as

$$y = \sqrt{\rho_{dl}} H^T \Delta \alpha + n \tag{3.18}$$

where $\Delta \in R_+^{MxS}$ is the antenna-selector matrix, which is represented by the antenna switch block in figure3.3. Another representation of (3.17) is in terms of the complete precoded signal as follows:

$$y = \sqrt{\rho_{dl}} H^T Diag(\alpha) x + n \tag{3.19}$$

Focused on some selection criterion, the antenna selection algorithms yield the selection vector,

$$\alpha_m = [\alpha_1, \alpha_2, \dots, \alpha_M]^T \in (0,1)^M$$

in which $\alpha_{\mathrm{m}} = 1$, indicates that the antenna with index M ,was selected.

where $x \in \mathrm{C}^{Mx1}$ the complete precoded signal and, $\alpha \in R_+^{Mx1}$ is the antenna selector vector that has the following structure

$$\alpha_{\mathrm{m}} = \begin{cases} 1, \text{if antenna m is selected} \\ \quad 0, \text{other wise} \end{cases} \tag{3.20}$$

the selection vector must fulfill

$$1_M^T \alpha = S \tag{3.21}$$

where S is the number of selected antennas. We can form the S -selected channel matrix

$$H_s = rem\big(diag(\alpha)\big)H = \Delta^T \Delta \tag{3.22}$$

where Δ is the antenna selection matrix. We can obtain matrix Δ by removing the zero columns of the diagonal matrix diag (α). Definitely, the rem (.) operator indicates the action of eliminating the zero columns of a given matrix.

3.4.2. Antenna Selector Matrix

The antenna selector matrix Δ presented in (3.22) is a supreme importance to the algorithms that would be obtainable in this chapter. The antenna selector matrix is a permuted version of the identity matrix with a condensed number of columns, which are selected from the supp (a). Further, due to the construction of Δ, the antenna selector matrix and the antenna selector vector have the succeeding property

$$diag(a) = \Delta\Delta^T \tag{3.23}$$

The structure of the antenna selector matrix is looser to describe with a figure sample, as the subsequent one. Example 3.1. Consider a MIMO system with M = 6 antennas at base station and S = 4 active antennas. Considerate an antenna selector vector given by

$$a = [0\ 1\ 0\ 1\ 1\ 1]^T$$

First it is necessary to get the support of a which is given by

$$supp(a) = \{2, 4\ ,5, 6\}$$

Then matrix Δ is given by

$$\Delta = [e_2, e_4, e_5, e_6]$$

$$= \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

thus yielding

$$\Delta\Delta^T = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Diag(a) \quad = \begin{bmatrix} 0 & & & & & \\ & 1 & & & & \\ & & 0 & & & \\ & & & 1 & & \\ & & & & 1 & \\ & & & & & 1 \end{bmatrix}$$

The most common criterion used to select the antennas at downlink Ma-MIMO is achieving the downlink sum-rate. Moreover, in this thesis a recent method exploited some antenna selection algorithm principles are presented in downlink Ma-MIMO that key for the desired antennas are selected from limited candidate antennas with high channel gain efficiently for relevant users. To better describe the algorithm, we proposed existing ASA like that of random antenna selection algorithms, norm based antenna selection algorithm and greedy antenna selection algorithm. As stated in section (3.1) during our execution we assumed that the BS was working with perfect channel state information and the feedback channel is assumed to be error-free and zero-delay, which represents the ideal case, where h_k is kxs independent and identically distributed for the Rayleigh fading channel matrix and the CSI with zero delay is optimal transmission. In this case zero force beamforming is used to cancels the multi-user interference and it achieves high performance.

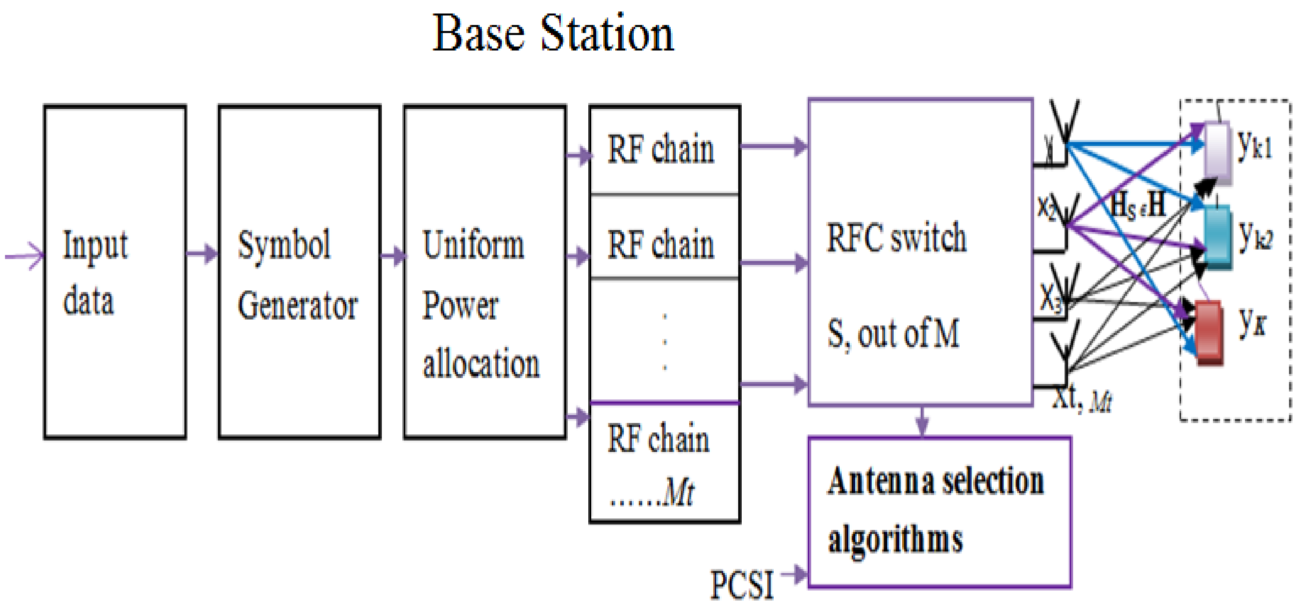

Figure3. 3: System design model for antenna selections algorithms.

3.5. The Problem Formulated over all Realizations for the Sum-rate

The circuit power consumption involves that the maximal achieved sum-rate is not necessarily maximized when all the RF chains available at the downlink Ma-MIMO transmitter are activated which means that the power consumed in the circuit when all the antennas activated may not produce the required maximum sum-rate. Hence, sub-optimal number of antenna $\sum_{\mathrm{m}=1}^{\mathrm{M}} \alpha_{\mathrm{m}}$ that maximizes the sum-rate should be derived by finding an optimal solution with antenna selection and equal power allocation among the users. Moreover, the aim is to find the optimal balance between the portion power consumed by the RF chains $\sum_{\mathrm{m}=1}^{\mathrm{M}} \alpha_{\mathrm{m}}.\,\mathrm{p}_{\mathrm{cir}}$ and the portion transmitted power, $\mathrm{p}_{\mathrm{out}}$. The number of RF chains should be optimized jointly with adequate antenna selection strategy and transmitted power must be allocated uniformly between users [59]. Critical problem is to find optimal solution with antenna selection and uniformly allocation power among user. The problem can be formulated overall realization for the average sum–rate.

$$\max_{P,\alpha_m: m=1\dots M} \mathrm{R} = E\left(\sum_{k=1}^{K} R_k\right) \tag{3.24}$$

$$\text{sub. to} \quad \sum_{k=1}^{K} Pk + \sum_{m=1}^{M} \alpha_m . p_{cir} \le Pmax \tag{3.25}$$

$$\sum_{m=1}^{M} \alpha_m \ge K \tag{3.26}$$

$$\text{where, } \alpha_m \ \epsilon \ (0,1), m = 1 \dots M \tag{3.27}$$

Hence, an antenna selection strategy is necessary to find the optimal number of antenna that maximize the sum-rate [59]. Consequently, the problem becomes combinatorial with exponential complexity growth in M and its non-convex due to the multi-user interference. Hence, the formulated problem is non-convex. The problem given in equation (3.25) is simplified and the sum rate is approximated when the transmitter power is equally allocated among user and optimal number of antenna is nominated through find the number of antenna that yield greatest sum-rate form the existing M antenna.

3.6. Random Antenna Selection Algorithm

Antennas are chosen randomly and a possible solution is to perform random antenna selection, which is a naive solution that randomly selects S out of M antennas. Hence, this strategy may not more guarantee to select the best antenna [66],[74]. The common method of the best antenna selector scheme is through greedy and norm based algorithm. Hence, random antenna selection algorithm with the least computational simplicity and with low accuracy in small number antenna at BS. Then, it is in more case used to provide a performance lower bound, but RAS is some preferable as BS antenna large. In this section, equal power received between users is assumed and the sum-rate over channel realizations is approximated for the problem stated in (3.25). Then, we derive randomly the optimal number of antennas that achieve the sum-rate over channel realizations assume under equal power allocated.

$$p_k = \frac{p_{out}}{K}, k = 1 \dots K \tag{3.28}$$

To find antenna that achieve the system of sum-rate for random antenna selection, let S denotes the cardinal of the set of selected antennas.

$$S = \sum_{m=1}^{M} a_m \tag{3.29}$$

where the vector $\alpha = [\alpha_1, \alpha_2 \dots \alpha_M]$

Under the multi-user interference the term is approximated by its expectation as K, S is infinite, as follows:

$$\frac{1}{K}\sum_{i=1,i\neq k}^{K} \left|h_k(a)h_i(a)^{H}\right|^2 \approx E\left\{\left|h_k(a)h_i(a)^{H}\right|^{2}\right\} \tag{3.30}$$

Also $E\left\{|h_k(a)h_k(a)^H|^{2}\right\}$ $=S^2$ and $1/\eta^2 = 1/T_r\left\{(H(a)H(a)^H)^{-1}\right\} \rightarrow \frac{S}{K} - 1$ [59]. Where S^2 is desired signal and assuming that the matrix channel is random $h_k(a)^H$, where $h_k(a)$ is the channel vector that assigned the propagation channel between the number of antenna at the BS and the Kth users. $H_s \epsilon C^{KXS}$ is channel matrix after antenna selection, so that the received signal over the effective channel $h_k(a)h_k(a)^H$ treated the noise and extends over a massive number of achievements of the fast-fading factors. The transmitted uniformly allocated power for user k can be expressed as

$$p_k = \frac{P_{max - S(H)P_{cir}}}{K} \frac{d_k^{-a}}{d_0^{-a}} \tag{3.31}$$

where S(H) is the set of entirely possible H

By replacing the circuit power consumption constraint we obtain the sum-rate over the channel realizations [59].

$$\bar{R} = k \sum_{k=1}^{K} log_2 \left(1 + \frac{(p_{max} S(H) - E\left|h_k(a) h_k(a)^H\right|^2 P_{cir})}{K(p_{max} - \sum_{m=1}^{M} a_m p_{cir} + K)} \right) \tag{3.32}$$

where, k is a positive constant which controls the quality of the approximation which approximate to 0.01n/m [66], H_s is randomly selected antenna from total antenna M, or channel matrix H, K a number of users, Pmax maximum power of the system, $h_k(a)$ channel between BS and users K, $h_k(a)^H$ random channel vector for user K and P_{cir} circuit power consumption. Though, this is a simplified form, the channel matrix is equivalent to solving a subset selection and optimal number of antennas that achieve sum-rate is given by

$$s^* = \underset{H_s \in H}{argmax(\bar{R})}, 0 < S^* < p_{max}/p_{cir} \tag{3.33}$$

Where, P_{max}/P_{cir} is the maximum number of antennas that can be supported by the system due to circuit power constraint. It is desirable to choose an approach with complexity increasing linearly with M. Then, the optimal number of antenna over channel realizations can be derived as

$$S^* = \begin{cases} \lfloor x \rfloor \; if \;\; \bar{R}(\lfloor x \rfloor) > \bar{R}(\lceil x \rceil) \; or \; \lfloor x \rfloor = \lfloor P_{max}/p_{cir} \rfloor \\ \lceil x \rceil, \quad otherwise \end{cases} \tag{3.34}$$

$wher \quad x = \frac{p_{max} + K - \sqrt{K(p_{max} + K)}}{p_{cir}} < \frac{p_{max}}{p_{cir}}$ and $\lfloor . \rfloor$ denotes the floor function, and $\lceil . \rceil$ the ceiling function.

The optimal number of antenna allow to determine the amount of power consumed at the radio ferquency chain.

where the effective SNR over the channel realizations is approximated as

$$\text{SNR} = \frac{p_k \left| h_k(a) h_k(a)^H \right|^2}{K \sum_{i=1, i\neq k}^{K} p_i \left| h_k(a) h_i(a)^H \right|^2 + \sigma^2} \tag{3.35}$$

Algorithm 1: Random Antenna Selection (RAS)

```
1: Input: H;
2: Initialization $\alpha_m \leftarrow 0, m = 1{:}M$ ; $a_{m^*} = \{\emptyset\}, a = \{1,2, \ldots M\}$
3: Select randomly s from indices of $a$ and use them to form $a_{m^*}$
4: set $a_{m^*} \leftarrow 1$ for $m^* \in a_{m^*}$
5: compute equation (2.32) sum-rate of s selected channel matrix $H_S$
```

Lastly, the number of antennas that achieve the instantaneous sum-rate (for one channel realization) should be derived; in consequence, the number of RF chains should be achieved jointly with adequate antenna selection strategy.

3.7. Norm-Based Antenna Selection Algorithm

Various antenna subset selection algorithms have been reported in literature in the past LTE network. Among those NBS is one of low complexity antenna selection schemes in Ma-MIMO with the number large M at BS [75],[76]. However, the optimal ESA exploring every possible combination from a set of value and often implemented recursively an expression such that each term is generated by repeating particular mathematics oppression and its use recursion do not use any loops ,however it may be applicable for combinatorial and logic programming. Optimal ESA is brute force approach techniques that straight for word approach based on problem statement and it's not applied for certain domain for a time. Combinatorial optimization uses, an objective function, predict problem that specify feasibility criteria and solution space universally of all possibly solution and extreme maximum or minimum requirement called candidate solution or feasible solution The brute force technique that is normally used for solving combinatorial optimizations problems. Some advantage exhaustive search algorithm is wide applicable, simplicity for MIMO wireless network as well as min activity selection.

The weaknesses of exhaustive search algorithm rarely yields efficient algorithms as number of activities increased and not as construct and creativity as some other design techniques due to its high complexity. The general framework of ESASA is generating all combinatorial structure that represents all feasible solutions and searches the best solutions among generated feasible solutions. The combinatorial explosion is a scenario where small increase input list the large increase in the generation of the structure, even though the solution for this problem looks simple, in reality. For instance where the solution involves possible selection of $\binom{64}{8} = {}^{64!}/_{8!\,(64-8)!}$. Its choice this make search a difficult process .ESA follows as: First it explores entirely possible combining or exhaustively check all options, check whether the queens are in beginning position and repeat steps one and two until availed configuration is done. Therefore, for the exhaustive search antenna selection algorithms is not necessary to directly use in Ma-MIMO antenna selection due to it have the high-complexity matrix inversion to calculate the throughput value of each antenna subset. Obviously, the exhaustive search is not feasible for the massive MIMO systems due to the tremendous searching space. In contrast to the high complexity exhaustive search, norm based antenna selection algorithms have low computational complexity in massive MIMO antenna selection as M number of antennas BS is large and for the NBS, only norm of the columns are evaluated.

Norm based transmit antenna selection permits to attaining Ma-MIMO gains without the expensive and complex implementation of as many radio frequency chains as antennas at the transmitter. Totally the procedures declared in the following sections, perform processes assuming full and perfect channel knowledge at the transmitter [77]. In real systems the channel matrix can be predictable from the training order contained in each transmitted frame. Subsequently, acquisitions of the channel matrix, columns of this matrix are selected depending on the selection algorithm. This stimulates the want of fast antenna selection algorithms as declared in [77]. It is simplest antenna selection algorithm. The technique is encouraged by the fact that selection founded on maximum norm maximizes the signal-to-noise ratio and minimizes the instant probability of error at the receiver [78]. Norm-based antenna selection is used because of its low computational complexity and better achieved sum-rate in Ma-MIMO. This method calculates the Frobenius norm of all the columns of the channel matrix H_{Mt} and selects only that subset which has maximum norm. The resulting sub-channel matrix would contain S_m out of M_t columns of the corresponding channel matrix H_{Mt}.

It's a good solution for antenna selection lies in switching-on the S_m antennas whose corresponding columns of the channel matrix have the highest norm. We have been proposing for achieving sum- rate with equal power allocation overall the antennas. Recently, this solution has also been shown to provide near-optimal performance even when the columns of the channel matrix are correlated [79]. That is why we can use NBS as a solution for transmitting antenna selection for massive MIMO. Moreover, NBS and the iterative search provide more approach effects when the small BS antennas exist, however as reviewed NBASA low performance as M BS antenna most large due to channel correlation.

Therefore, in this case, the throughput is governed by the total power in the channel, and the NBS approach becomes sub-optimal. In addition, from (3.41), it is clear that the individual contribution of each antenna proved the rate (throughput) is through its contribution to $||H||_F^2$. As discussed in previous the number of RF chains at the BS and antenna equipped equal and the number of selected antenna are (S$\geq K$). In this case assuming zero-forcing which is a simple linear precoding technique capable of achieving an almost better performance and minimize multi-user interference (MUI) [77], was applied. In multi-user Ma-MIMO systems, the signals received by terminals can be expressed as follows.

$$y = Gx + n \tag{3.36}$$

where G is $D^{1/2}H$ and $H \epsilon C^{MxK}$ is the channel matrix, given by

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M} \\ \vdots & & \ddots & \vdots \\ h_{K1} & h_{Km} & \cdots & h_{KM} \end{bmatrix} = [H_{\overline{K}1}, H_{\overline{K}2}, \dots, H_{\overline{K}M}] \tag{3.37}$$

In (3.37), h_{km} is a channel element from the mth transmit antenna to the k^{th} user (m =1,2,...,M;k =1,2,...,K);$H_{\overline{K}m}$ denotes the K×1 channel vector between the mth transmit antenna and the K users. It is expected that the elements of H can be demonstrated as independent and identically distributed (i.i.d) complex Gaussian random variables with zero-mean and unit-variance (Rayleigh fading). Moreover, the terminals are deliberated to have full knowledge of the channel matrix H and transmit it to the BS without any errors or time delays. The signals received by the kth user can also be expressed as

$$y_k = \sqrt{p_k} h_{K\bar{M}} v_k s_k + \sqrt{p_i} \sum_{i \neq k, i=1}^{K} h_i \, v_i + n_k \tag{3.38}$$

Where $v = [v_1, v_2, \dots v_K]^T$ is the zero forcing precoding matrixes equal $H^H (HH^H)^{-1}$.

Supposing that the received signal–to-noise ratio is the identical for all users, the received signal-to-noise ratio is given by

$$SNR = \frac{P_d}{T_r \left\{ \left(H_{k\overline{M}} H_{k\overline{M}}^H \right)^{-1} \right\} \sigma^2} \tag{3.39}$$

Spatial multiplexing can also be used for instantaneous transmission to several users, known as space-division multiple access (SDMA), in which CSI is estimated at the transmitter. The users instantaneously receives data from each antenna with different channel gain and with different spatial signatures. As to be observed in figure below the norm of the column of each antenna channel gain evaluated in (3.40).

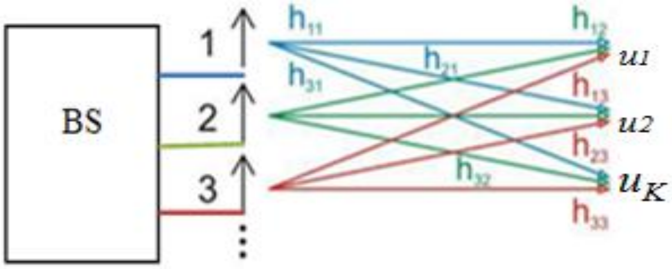

Figure3. 4: Basic Diagram of Ma- MIMO System [77].

The norm of each column of the channel matrix is first calculated as follows based on (3.40),[77].

$$\| H_{\bar{K}m} \|^2 = \sum_{i=1}^{K} | h_{im} |^2 = | h_{1m} |^2 + | h_{2m} |^2 + \cdots | h_{Km} |^2 \tag{3.40}$$

where $H \in C^{K \times \mathrm{M}}$ is the channel matrix

The columns of H are then arranged in descendant directive, resulting in the novel matrix

$$H_{nbs} = [H_{\overline{K}1}, H_{\overline{K}2}, \dots H_{\overline{K}M}] \tag{3.41}$$

The first transmit-antenna selected of the size KxS is formed by the columns $\|H_{\overline{k}1}\|^2$ to $\|H_{\overline{K}M}\|^2$ and we determine the index of the column vector H_{Ki} with the largest norm gain ($H_{\overline{K}i}$), i=1, 2,...M using algorithm below to achieve sum-rate [77],[78]. This scheme including initialization step and iterative updating step, respectively and both steps use the vector norm as criteria which considerably decrease each iterative computation complexity.

$$R_{nbs} = \sum_{k=1}^{K} log_2\left(1 + \frac{p_k\|H_{\overline{K}m}\|_F^2}{M^2K\sigma^2}\right) \tag{3.42}$$

$$m^* = \underset{m\ \in \Delta}{argmax(R_{nbs})} \tag{3.43}$$

The effective SNR over the channel realizations at user K is approximated as

$$SNR = \left(\frac{p_k|H_{kM}v_k|^2}{\sum_{i\neq k,i=1}^{K} p_i|H_{i\overline{M}}v_i|^2 + \sigma^2}\right) \tag{3.44}$$

Algorithm 2: Norm-based antenna selection algorithm (NBASA)

```
1: Initialization
2: $\alpha_m \leftarrow 0, m = 1{:}M$ ;
3: $\Delta \leftarrow \{m, m = 1{:}M\}$ set of antenna selected matrix;
4: m=1
5: For k=1: K calculate $\|H_{\overline{K}m}\|_F^2$ ;
    Select the norm of the column that has high channel gain efficiently
    Compute equation (3.42) sum-rate of (Rnbs)
    $m^* = \underset{m\epsilon\Delta}{argmax(R_{nbs})}$
    $\Delta \leftarrow \Delta\backslash\{m^*\}$
```

```
                    end
        6: If m=M terminate the algorithms
                else
                 m=m+1 go to step (5)
                end
```

3.8. Greedy Antenna Selection Algorithm

In Ma-MIMO from (3.6) above the signal received by terminals k^th^ can be written as

$$y_k = \sqrt{p_k}\sqrt{\beta_k} h_k(a) w_k(a) s_k + n_k \tag{3.45}$$

Later on ZF precoder is used to reduce the multi-user interference and assuming a perfect CSI knowledge at the transmitter the second term (3.6) in drops to zero. A greedy algorithm approach solves the optimization problem which demands the maximum or minimum result problem and its simplest and straight forwards approach techniques. The decision is taken on the basis of currently available information and does not worry about the effect of a current decision in the future. Some problems require minimum result or maximum result. If a problem requires either minimum or maximum result, then we call that type of problem as optimization problem.

Solution which satisfies a condition given in a problem is a feasible solution. There are many feasible solutions however; the unique one is optimization solutions that are workable solutions which satisfy some constraint. According to greedy algorithm, a problem should be solved in stages. In every stage we will deliberate one input from an assumed problem. If that input is workable then we included in the solution and by including those all feasible solutions we get the optimal solution. The characteristic of GASA is to construct a solution in an optimal way. This algorithm preserves two set, one contains selected items and other includes rejected items. It’s made goods locally choose. Greedy algorithm has a constituent such as; an applicant set where a solution is formed from this set, a selection function where it does that used to select the best applicant to be added to the solution, a feasibility function where it’s used to determine whether a candidate can be used to give to the solution, an objective function were used to assign value to a solution or partial solution and a solution function where it's used to indicate whether a complete solution has been reached. This algorithm may be applicable; to find the shortest path, activity selection problem and jobs sequence etc. Generally, the idea of greedy technique is the following, which means at every step you have a choice to choose. Instead of evaluating all choices recursively it picks the best one locally, and goes with that. Recurs and do the same. Therefore, basically, a greedy algorithm picks the nearby optimal choice expecting to get the globally optimal solution. Finally, it finds the optimal number of antennas that achieves the sum-rate [59]. Hence, the number of RF chains must be derived jointly with adequate antenna selection strategy. Consequently, we recommend a low complexity of greedy iterative algorithm that determines the number of optimal antenna achieving the instantaneous sum-rate and uniformal power allocation at each iteration for a fixed number of antennas. The best antenna m^* that maximizes the sum-rate is determined among the set of antenna selection metric Δ. The best antenna should minimize the term efficiency power amplifier; hence the best antennas at each iteration can be derived as

$$R_g = \sum_{1=k}^{K} log_2 \left(1 + \frac{p_k \beta_k |h_k(a) w_k(a)|^2}{\sigma^2 \left((\alpha_m)_{1=m}^{M} \right)} \right) \tag{3.46}$$

$$m^* = \underset{m \in \Delta}{argmax} \, (R_g) \tag{3.47}$$

the selected antennas are given (m^* corresponds to S^*), and uniformly power distribution among users is given (3.31).

Where the effective SNR over the channel realizations is approximated as

$$\text{SNR} = \frac{p_k \beta_k |h_k(a) w_k(a)|^2}{\sum_{i=1 \neq k}^{K} p_i \beta_k |h_k(a) w_i(a)|^2 + \sigma^2} \tag{3.48}$$

Algorithm 3 Greedy antenna selection (GAS)

```
initialization;
$\alpha_m \leftarrow 0, m = 1{:}M$ ;
$\Delta \leftarrow \{m, m = 1{:}M\}$ set of antenna selected matrix;
for S=K+1:$\lfloor p_{max/}p_{cir} \rfloor$ do
    Select the best antenna $m^*$ from $\Delta$ that minimizes efficiency power amplifier
    $\alpha_{m^*} \leftarrow 1$, activate antenna
    $\Delta \leftarrow \Delta \backslash \{m^*\}$
    compute equation (3.46)
    update the vector m for the next cycle
else
    Break If $R_s < R_{S-1}$
end for
```

Where at [59] algorithm $K/S - K$ denote η^2 as number of the best antenna increase eta decrease. The convergence of the suggested algorithm is acquired when the instantaneous sum-rate starts declining $(Rs < Rs - 1)$. Therefore, the above proposed algorithm allows determining the number of RF chains, the selected antennas through assuming uniform power allocation between terminals and the attained sum-rate using pseudo-code greedy algorithm method.

CHAPTER FOUR

4.1. Simulation Result and Discussion

In the previous chapter three mathematical models for sum-rate, energy efficiency and antenna selection algorithms of downlink large scale MIMO system under TDD operation was analyzed and investigated comparison among the proposed algorithms. Where base station antennas having prefect CSI and number of antenna M, greater and greater than K terminals.

This chapter presents the numerical results and simulation under a different scenario.

- The achieved sum-rate versus variable transmit antenna selected (S)
- The achieved sum-rate versus variable number of transmitted antenna (M)
- The achieved sum-rate versus variable number of users (K)
- The achieved sum-rate versus variable SNR
- Evaluating EE based on achieved sum-rate of through transmit antenna selected (S), user (K), SNR and number of transmit antenna (M)

The current mobile technology convinces the high mobility with high level hustle of data rates and high capacity IP based services and applications are standardized. The parameter is associated through advanced LTE standardized. Values of different parameters used for simulation is given below table.

Table4. 1: Value of different parameters [57],[59].

Parameter	Value
Number of antennas at single BS when varied (10 to 256) (M)	256
Number of user terminals (varied) (K)	40
Maximum transmit power (P_{max}) fixed	10[dB]
Path loss exponent (α)	3.8 [dB]
Number of channel realization	1000
Maximal user distance from base station d^k (35-3200) varied	3200 m
Minimal user distance from base station d_0 (2-35) varied	20 m
Factor φ	1
Bandwidth	20MHz
P_{syn},P_{bb} ,P_{DAC},P_{mix}, P_{filt}	60mW,70mW,15.6mW,30.3mW,20mW

4.2.The DL Ma-MIMO System by Assuming TDD Operation at the Transmitter of PCSI.

- **Achieved sum-rate by varying the number of transmitting AS (S out M)**

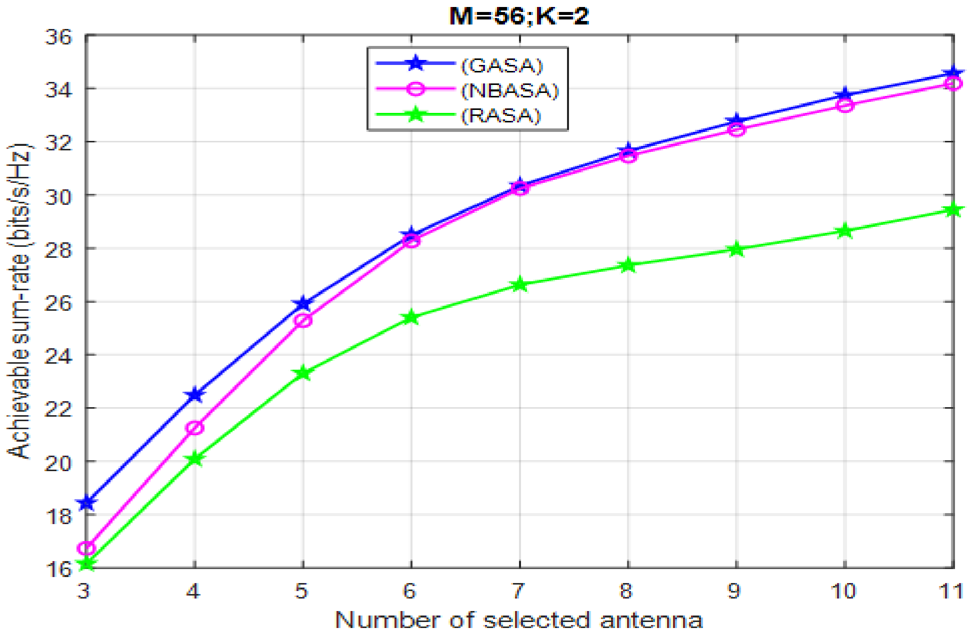

Figure4. 1: Achievable sum-rate versus number of selected antenna under GASA, NBASA and RASA when variable number of selected antennas. As (M=56, K=2 and 10dB).

Table 4.2: Value of achievable sum-rate (R) versus number of selected antenna (S) under GASA, NBASA and RASA at 10 selected antennas for figure 4.1 above. Based on table 4.2 same discussion procedure governed for all bellow out come result.

Parameter	Environment (i.i.d) random,variable distribution	Antenna selection algorithms		
M=56,K=2,10dB	DL-Ma-MIMO systems	For example at 10 selected antenna for figure 4.1		
Transmitted number of selected antenna (S)		RASA	NBASA	GASA
Achievable sum-rate		28.4 (bits/s/Hz)	33.7 (bits/s/Hz)	33.9 (bits/s/Hz)

As shown the above figure 4.1 achieved sum-rate by GASA is compared to the norm-based antenna selection algorithm and random antenna selection at the transmitter when the numbers of selected antennas from M, antennas are varied, under equal power available at the BS. GASA gives the highest achievable sum-rate than an NBASA and RASA at small and large number of M, antenna at single BS. If we compared the NBASA, RASA and GASA, GASA gives the best performance achieve sum-rate because in each stage, it considers one input from a given problem and its selected scenario is iteratively select antenna that have high channel gain antenna depending on the current activity and remove the worst antenna through its iteration. Hence, as a number of activated antenna increases, GASA achieved best sum-rate than NBASA and RASA. In addition, it’s poor affected by channel correlation. NBASA performance poor at initial stage selected antennas, after that it rapidly increases from 3 to 6 antenna and being to bending when number of selected antenna reach 8 antenna, because of several selected antennas increases the correlation among the channel increase. As declared NBASA not consider the correlation of the channel its simple select the channel that with a high norm of column vector. RASA performance rapidly increases sum-rate at first stage from 3 to 6 selected antennas after that it going to bending. However RASA is not having complexity and it have same good performance related to

GASA and NBASA as activated antenna increases. Although NBASA perform the better achieved sum-rate when transmit antenna selected out of M. However when the RASA and NBASA are compared, NBASA has approach performance to achieved sum-rate at the beginning, but as the number of selected antenna increased its performance approaches to the GASA to achieve same-rate, so the NBASA have better performance than RASA as number of selected antenna increase from BS antenna its almost approaches to GASA preformance from 6 to 8 selected antenna. Both GASA and NBAS are separated after eight antenna selected and bending. For example at 10 selected antenna GASA,NBASA and RASA achieved sum-rate 33.9 (bits/s/Hz),33.7 (bits/s/Hz) and 28.4 (bits/s/Hz) respectively. Finaly when GASA compared with NBAS and RASA it have more significant enhancement of sum-rate for the system performance.

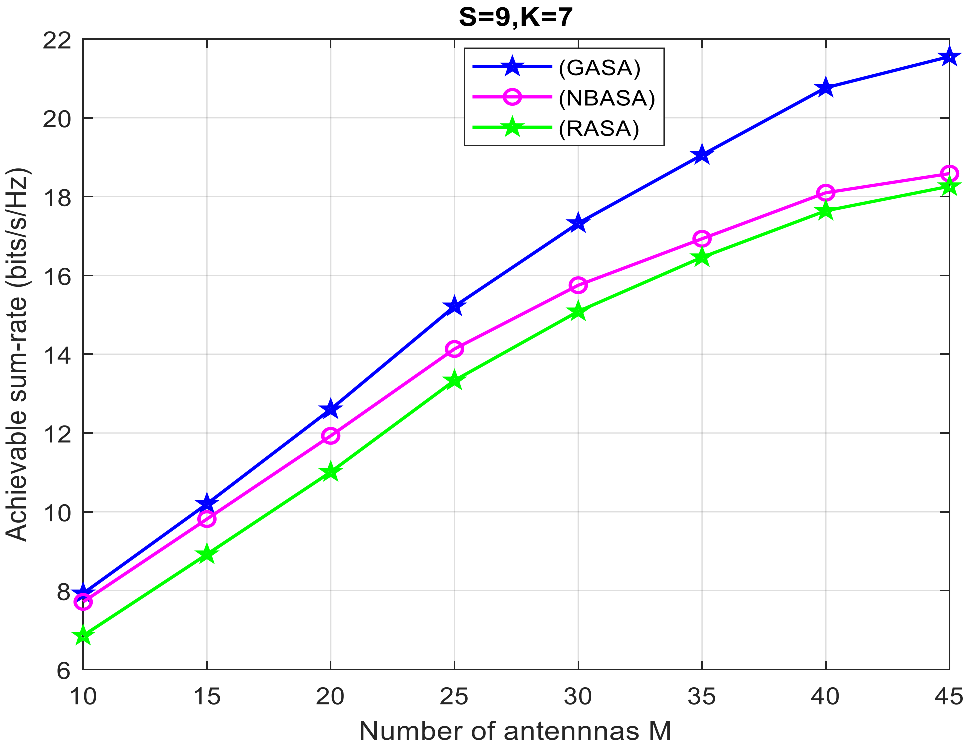

Figure4.2: Achievable a sum-rate versus number of TA, M under GASA, NBASA and RASA. For instance (K = 7, S=9, and 10dB).

As shown the above figure 4.2 when the sum-rate achieved by GASA is compared to NBAS and RASA at the variable M, transmitter antennas and under equal power available at the BS. The three simulated AS schemes approach the performance bound given by the number variable M, antennas case with different slopes. Among the comparison between GASA, RASA and

NBASA, GAS the best performance to be achieved sum-rate at large number of transmit M, antenna, whereas NBASA performs the higher sum-rate at small number of transmit antenna than RASA. As far as number of M transmitters antenna increases the performance of NBASA to achieve sum-rate becomes lower of GASA and crouching to RASA because of channel correlation exists and it slowly being bending start from 40 to 45 M transmit antenna to approach the RASA. On the other hand, RASA have the least performance at the beginning, but as the number of transmission M, antenna increases the performance of RASA to achieve sum-rate increases. For example,at 30 transmitted antennas GASA,NBASA and RASA achieved sum-rate 17.7 (bits/s/Hz),15.8 bits/s/Hz) and 14.9 (bits/s/Hz) respectively. Lastly, GASA gives the highest achieved sum-rate when the number of M, TA increases. While the performance gaps between NBASA and RASA at 43 to 45 M, transmission antenna achieves more approached sum-rate.

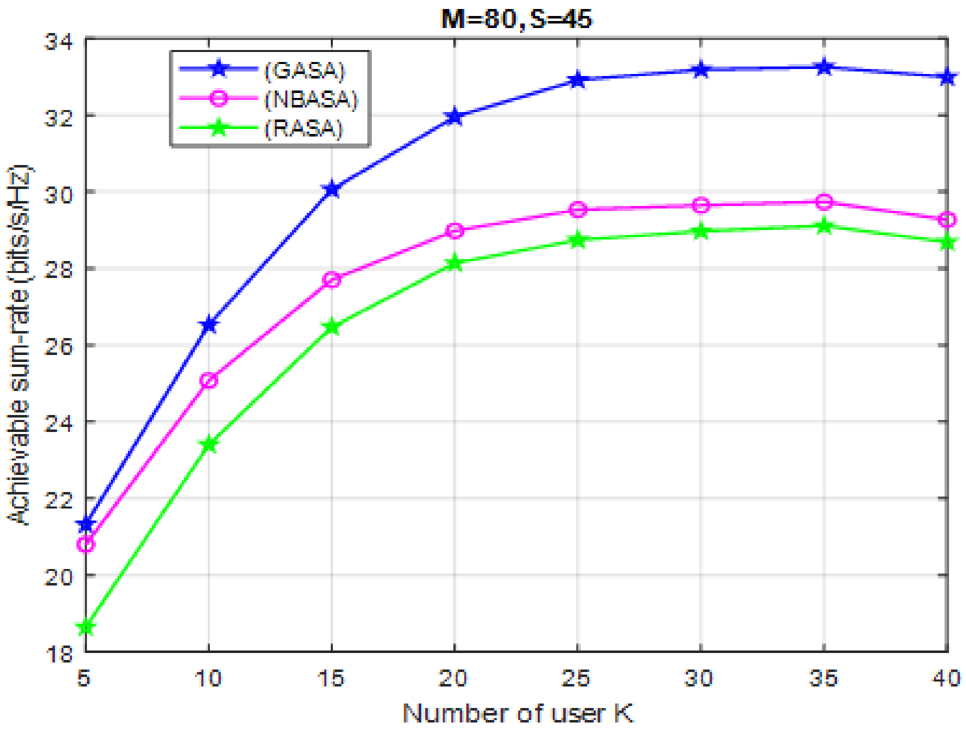

Figure4. 3: Achievable sum-rate versus number of users under GASA, NBASA and RAS with variable of the number of users at (M=80, S=45 and 10dB).

As shown the above figure 4.3 the achieved sum-rate versus number of user K. Now we afford investigate the impact of the large number of users K on the system performance to achieve sum rate. In figure 4.3, we realize the achieved sum-rate of throughputs as a function of the number of users under the proposed GASA, NBASA and RASA. The optimal number of users that gives the highest achieved the sum-rate can be observed by GASA as it iteratively selects a number of transmitted best antennas than NBASA and random antenna selection. It rapidly enhancement the sum-rate as user increases from 5 to 20 after that it's bending. NBASA rapidly increase sum-rate at user varies from 5 to 15 and it form bending, saturation and deteriorated as the impact of a large number of user exist. Moreover, as the number of users increases, the sum-rate achieved by NBAS and RASA remains to raises and it converges rapidly than GASA when a large number of users exist. Therefore, GASA achieves the highest sum-rate at a large number of users than NBASA and RASA. In addition, the NBAS better performance than RASA as the number of user increases. For example, at 25 number users GASA,NBASA and RASA achieved sum-rate 33.4 (bits/s/Hz), 29.8 (bits/s/Hz), and 28.4 (bits/s/Hz) respectively. Generally, we can clearly realize that GASA performs best achieved sum-rate than NBASA and RASA.

The performance of SNR verses achieved sum-rate for selected antennas.

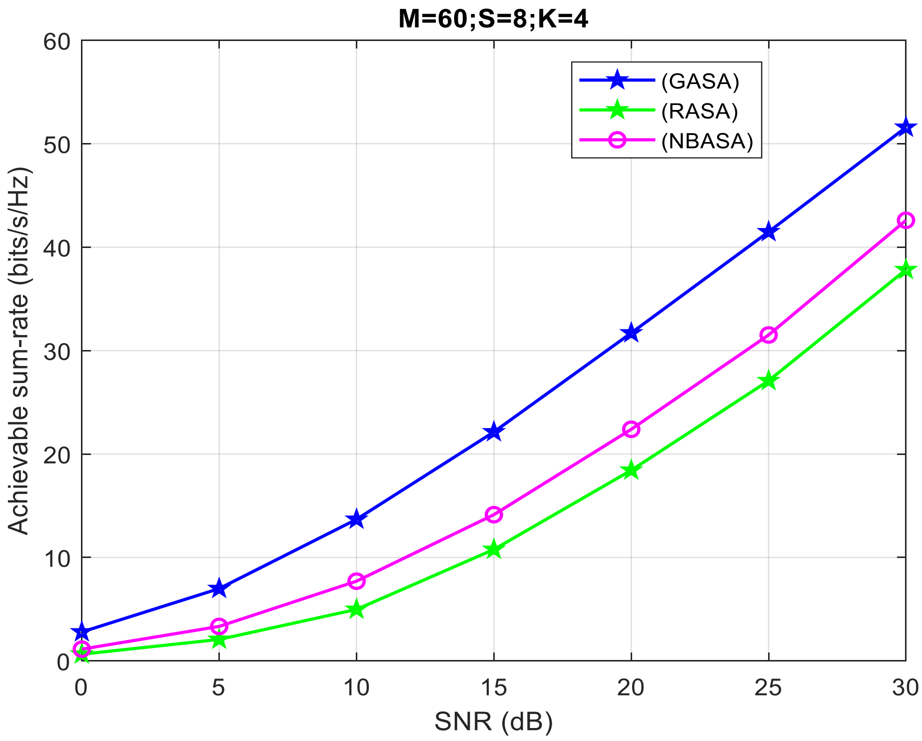

Figure4. 4: The achievable sum-rate versus SNR under RAS, NBS and GA antenna selection algorithm at (M=60, S=8, and K=4).

As shown the above figure 4.4 the achieved sum-rate performance for the NBAS, RAS and GA antenna selection versus SNR under uniform power allocation is shown. The sub-optimal selections are performed through an iterative GAS, whereas randomly selected antennas have lowest achieved sum-rate performance than GASA and NBASA. As the value of SNR increases the performance of those schemes is instantaneously enhance with different value. For instance, at 20dB, GASA,NBASA and RASA achieves sum-rate 31.8 (bits/s/Hz),23.5(bits/s/Hz) and 18 (bits/s/Hz**)** respectively. NBASA have achieved sum-rate performance that attitudes to GASA and better than RASA at small values of SNR. We observe that RASA clearly outperforms the antenna selection which achieves poor sum-rate than GASA and NBASA. Last of all, GASA achieves the greatest sum- rate than else at high SNR to give the best sum-rate.

4.3. Simulation Results for Evaluating EE versus Variable Number of TAS

System's energy efficiency is determined by total transmitted power and some number of transmitted selected antennas. Thus, we analyze the relationship between total transmitted powers, achievable sum-rate of throughput and assess energy efficiency based on number of transmitted selected antennas on the system performance separately.

4.3.1. Simulation for the evaluation of EE in terms of number of selected antennas.

To show the relationship between power consumption and achieved sum-rate, as discussed above, we simulate the system achieved sum-rate under a variable number of selected antennas. We assume channel is perfect CSI at transmitter side and by taking the achieved sum-rate of throughput through transmitted selected antenna, and we assess EE.

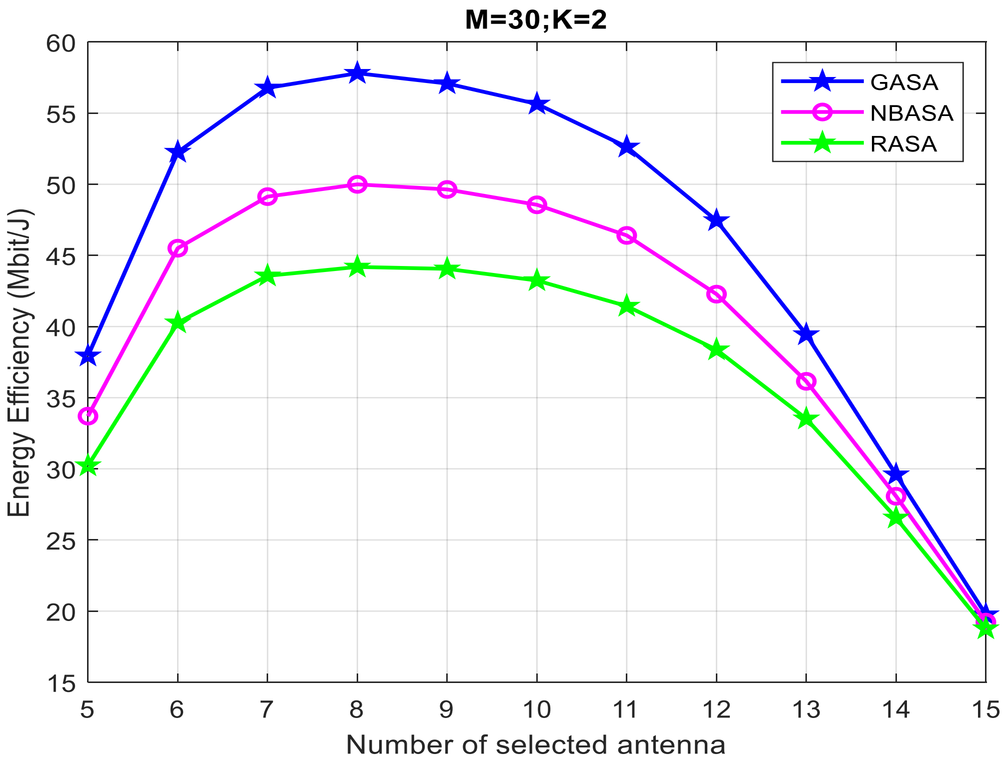

Figure4. 5: Achievable EE versus number of selected antenna under GASA, RASA and NBASA by variable of transmit antenna selected. For example (M=30, K=2 and 10dB).

Table 4.3: Value of achievable energy efficiency versus number of selected antenna (S) under GASA, NBASA and RASA at 8 selected antenna for figure 4.5. Based on table 4.3 same discussion procedure governed for all bellow out come result.

Parameter	Environment (i.i.d) random,variable distribution	Antenna selection algorithms		
M=30, K=2 and 10dB	DL-Ma-MIMO systems	For example at 8 selected antenna for figure 4.5		
Transmitted number of selected antenna (S)		RASA	NBASA	GASA
Achievable EE		44.9 (Mbit/J)	50 (Mbit/J)	58 (Mbit/J)

From the figure 4.5, at the above a variable number of activated antenna selected effect of the different algorithm shows assessment of EE, it’s clearly seen that GASA system has the best performance in terms of achieved energy efficiency among the NBASA and RASA. However, for those ASA from 1 to 7 selected antennas, EE increase rapidly by different value of EE and from 7 to 9 antenna effect of active selected antenna by those schemes being to bending, saturated, converge and declined because of as active selected antenna raise, circuit power consumption increases, multi-user interference (MUI) and attenuation (activate antenna increase Pcir increase) causes energy efficiency deteriorated. Hence, after nine antennas selected EE decrease or make curve and failed. However, when transmitted selected antenna increases, the EE increase for same selected antenna, but as we observed form below figure when selected antenna are more increase EE of RASA, NBASA and GASA are correspondingly breakdown. Since number of selected antenna increase NBASA and RAS does not have better EE into account, as GASA, and they perform poor in high PRS regime, however NBASA is better achieved EE than RASA. As a number of selected antennas are small from large number of M antennas the GASA, NBASA and RASA have raised EE, respectively. Typical RASA scheme has relatively poor performance, which is approaching to NBASA and GASA respectively. We clearly seen that properly achieved rate is not got when activating all radio frequency chains because activating all antenna menace activating circuit power consumption. Furthermore, growth the number of selected antenna degradation of EE to the system menace poor EE exist. Because of that fact the growth of the active antenna cannot significantly raise the EE. For instance, at 8 selected antenna GASA,NBASA and RASA achieves energy efficiency 58 (Mbit/J),50 (Mbit/J) and 44.9 (Mbit/J) respectively. Generally from this figure, we can conclude that GASA has the best system performance in terms of EE at perfect channel state information than other antenna selection scheme.

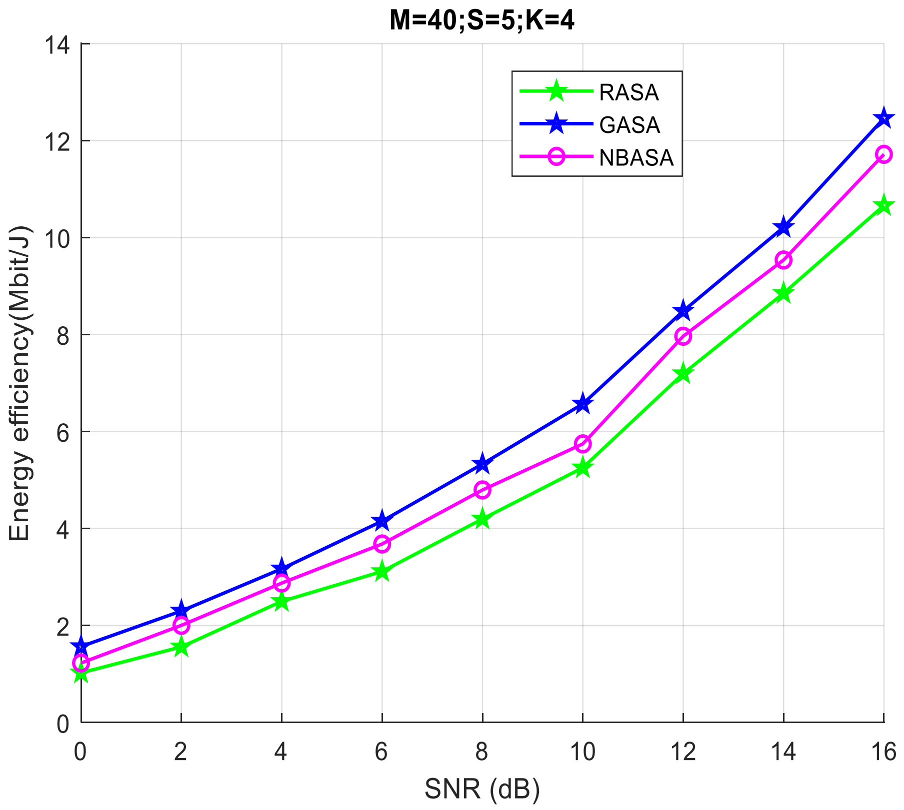

Figure4. 6: Evaluated EE with different SNR value for GASA, RASA and NBASA .As (M=40, S=5 and K=4).

As shown the above figure 4.6 the achieved EE against SNR. We can find that the proposed GASA achieves the highest energy efficiency than other three schemes. Particularly GASA achieved 12.4 (Mbit/J) EE as compared to NBAS and RASA. In this GASA is best energy efficiency performance than NBASA and RASA at different value of SNR. Within given range of SNR at 12dB GASA,NBASA and RASA achieves energy efficiency 8.2(Mbit/J),8 (Mbit/J) and 6.7 (Mbit/J) respectively. In addition, NBASA achieves better energy efficiency than RASA scheme. RASA have poor performance when compared to GASA, however approach to the NBASA. Consequently, the energy consumption caused by the RF chains can be significantly reduced by GASA than the NBASA and RASA scheme. Finally GASA, NBASA and RASA give the highest EE at the highest SNR.

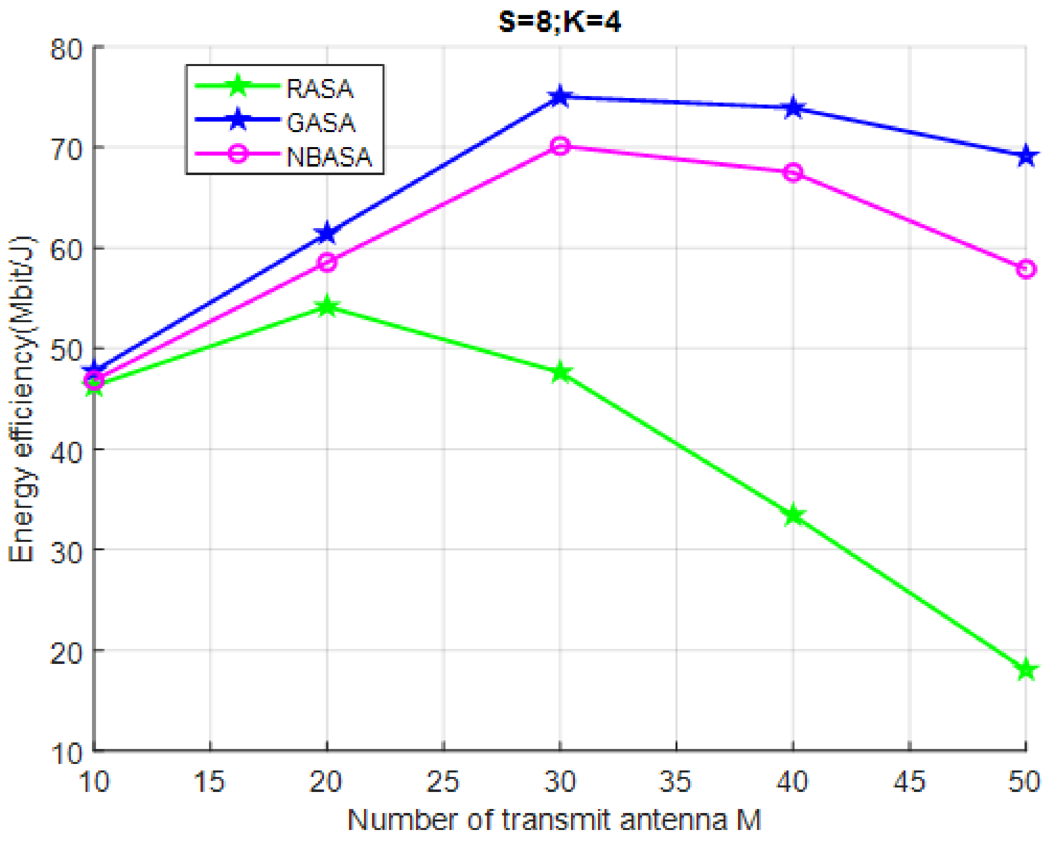

Figure4. 7: Achieved EE versus with variable number of transmit antennas M. As (K=4, S=8)

As shown the above figure 4.7 illustrates EE versus the number of transmit antennas M. It shows that the EE was affected by a large number of transmitting antennas at transmitting power 10watt in single cell multi users. The EE increased by antenna selection scheme with a large number of antennas when M equal 20, for GASA, NBAS and RASA simultaneously. Below figure 4.7 shows that the EE of those algorithms started to increase until the number of antennas M 20, 30, and 30 with different value respectively and after that becomes bend and deteriorated, as well as EE start to decrease according to the sufficient number of antennas for serving the number of users in the single cell correspondingly. While, the EE for GASA started to increase at some increases number of M transmit antennas until 75 (Mbit/J), however as number M antenna increase EE became converged. Because of unwanted power consumption in the RFC, the pcir was still needed for transmission so after this value, the EE started to decrease, due to more Pcir increase as M rise. For example, at M number of transmitter antennas 30, EE achieves by GASA, NBASA and RASA, 75 (Mbit/J), 71(Mbit/J), and 47 (Mbit/J) respectively. When the number of M antennas increases EE dropped. GASA is achieving best performance as number of M antenna increase when compared to NBASA and RASA. Whereas NBASA have better achieves EE than RASA as variable of M antennas. Finally increase number of BS antenna in single cell will increase transmit power and operating power consumption, which creates the tendency of concave shape for EE.

CHAPTER FIVE

5.1. Conclusion and Future Work

As the appearance of Massive MIMO, the system performance of wireless communication system has been improved significantly in terms of throughput, latency, more reliability and so on. In this thesis antenna selection algorithms analyzed and executed in downlink massive MIMO systems under assumption perfect CSI. The importance of downlink massive MIMO system model, mathematical model and problem formulation canvassed. In this system effective antenna selection algorithm such as GASA, NBASA and RASA at downlink Ma-MIMO base station able to analysis together based on achieve sum-rate evaluate EE by assuming power consumption.

In Ma-MIMO systems increasing number of BS antenna is crucial to the system performance, but circuit power consumption and radio frequency chains simultaneously increase to consume power. Additional in Ma-MIMO as the number of M, antenna and radio frequency chain increases the mathematical complexity of SINR, antenna selection scheme and channel correlation also increases. Therefore, to make the formulated problem to be solvable, we proposed antenna selection scheme like random antenna selection algorithm, norm based antenna selection algorithms and greedy antenna selection algorithms to address those problems.

Hence, from the proposed antenna selection technique GASA gives best sum-rate and assess EE performance than NBASA and RASA at large number of M antenna. Where NBASA gives approach performances to GASA at small M antennas while RASA gives the best approach performance to the NBASA and GASA respectively at the small and large M transmit antennas. However, GASA gives the best performance to achieved sum-rate and assess energy efficiency at small and large M transmits antennas. Finally, for those schemes combining numerical results and we presented that M- MIMO antenna selection algorithms remarkably achieves sum-rate and evaluate energy efficiency by assuming equal power allocation to users.

Massive MIMO antenna selection system is a key in next wireless communication system in order to significant achievable sum-rate and energy efficiency. There are motionless some features that should be done in the forthcoming.

5.2. Recommendations for Future Work

Here are points of testimonials to the conceivable elongations of the works of this thesis research:

- In this thesis analysis of Massive MIMO antenna selection algorithm schemes consider only a single cell downlink Ma-MIMO wireless network. In the future, it can be investigated to multi-cells Massive MIMO system which can maximize the sum-rate and energy efficiency.
- The massive MIMO antenna selection system with the ZF precoding considered minimizing MUI at PCSI and enhancing the performance with different parameters when the numbers of antennas are increased. The same system's performance can be enhanced in the future using another percoding like MMSE and RZF is open problem.
- A low complexity antenna selection algorithms scheme is assumed at downlink transmission base station. Therefore, it is desirable to study and corporate massive MIMO technology to significantly increased sum-rate and optimizes energy efficiency in very large –MIMO under imperfect channel state information.
- Optimal efficient antenna selection scheme and user scheduling with optimal power allocation in massive MIMO under different simple signal processing should be considered in the future for more accurate simulation results.
- The proposed selection schemes could be extended to systems to maximize energy efficiency through linear and non-linear precoding techniques Dirty Paper Coding (DPC) and Minimum Min square Error (MMSE), are open problem.
- A new search algorithm to find the optimum subset of antennas and maximize EE could be developed using the Branch-and-Bound (BAB) optimization method, which have been employed to solve different problems, especially in combinatorial optimization.

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